高等数学

积 分 表

公 式 推 导

目　　录

（一）含有 $ax+b$ 的积分（1~9）

1. $\int \frac{dx}{ax+b} = \frac{1}{a}\cdot ln\left| ax+b \right| + C$

证明：被积函数 $f(x)=\frac{1}{ax+b}$ 的定义域为 $\{x \mid x \neq -\frac{b}{a}\}$

令 $ax+b=t\ (t\neq 0)$，则 $dt = adx$，$\therefore\ dx=\frac{1}{a}dt$

$$\therefore \int \frac{dx}{ax+b} = \frac{1}{a}\int \frac{1}{t}dt$$

$$= \frac{1}{a}\cdot ln\left| t \right| + C$$

将 $t=ax+b$ 代入上式得：$\int \frac{dx}{ax+b} = \frac{1}{a}\cdot ln\left| ax+b \right| + C$

2. $\int (ax+b)^{\mu}dx = \frac{1}{a(\mu+1)}\cdot(ax+b)^{\mu+1} + C \qquad (\mu \neq -1)$

证明：令 $ax+b=t$，则 $dt=adx$，$\therefore\ dx=\frac{1}{a}dt$

$$\therefore \int (ax+b)^{\mu}dx = \frac{1}{a}\int t^{\mu}dt$$

$$= \frac{1}{a(\mu+1)}\cdot t^{\mu+1} + C$$

将 $t=ax+b$ 代入上式得：$\int (ax+b)^{\mu}dx = \frac{1}{a(\mu+1)}\cdot(ax+b)^{\mu+1} + C$

3. $\int \frac{x}{ax+b}dx = \frac{1}{a^2}\left(ax+b-b\cdot ln\left| ax+b \right|\right) + C$

证明：被积函数 $f(x)=\frac{x}{ax+b}$ 的定义域为 $\{x / x \neq -\frac{b}{a}\}$

令 $ax+b=t\ (t\neq 0)$，则 $x=\frac{1}{a}(t-b)$，$dx=\frac{1}{a}dt$

$$\therefore \int \frac{x}{ax+b}dx = \int \frac{\frac{1}{a}(t-b)}{t}\cdot\frac{1}{a}dt = \frac{1}{a^2}\int\left(1-\frac{b}{t}\right)dt$$

$$= \frac{1}{a^2}\int dt - \frac{1}{a^2}\int \frac{b}{t}dt$$

$$= \frac{t}{a^2} - \frac{b}{a^2}\cdot ln\left| t \right| + C$$

$$= \frac{1}{a^2}\left(t-b\cdot ln\left| t \right|\right) + C$$

将 $t=ax+b$ 代入上式得：$\int \frac{x}{ax+b}dx = \frac{1}{a^2}\left(ax+b-b\cdot ln\left| ax+b \right|\right) + C$

4. $\int \frac{x^2}{ax+b}dx=\frac{1}{a^3}\left[\frac{1}{2}(ax+b)^2-2b(ax+b)+b^2\cdot ln\left|ax+b\right|\right]+C$

证明:$\int \frac{x^2}{ax+b}dx=\frac{1}{a^2}\int \frac{(ax+b)^2-2abx-b^2)}{ax+b}dx$

$$=\frac{1}{a^2}\int (ax+b)dx-\frac{1}{a^2}\int \frac{2abx}{ax+b}dx-\frac{1}{a^2}\int \frac{b^2}{ax+b}dx$$

$\because \frac{1}{a^2}\int (ax+b)dx=\frac{1}{2a^3}(ax+b)^2+C_1$

$$\frac{1}{a^2}\int \frac{2abx}{ax+b}dx=\frac{2b}{a^3}\int \frac{ax+b-b}{ax+b}d(ax)$$

$$=\frac{2b}{a^3}\int dx-\frac{2b^2}{a^3}\int \frac{1}{ax+b}d(ax+b)$$

$$=\frac{2b}{a^3}x-\frac{2b^2}{a^3}ln\left|ax+b\right|+C_2$$

$$\frac{1}{a^2}\int \frac{b^2}{ax+b}dx=\frac{b^2}{a^3}\int \frac{1}{ax+b}d(ax+b)=\frac{b^2}{a^3}ln\left|ax+b\right|+C_3$$

由以上各式整理得:$\int \frac{x^2}{ax+b}dx=\frac{1}{a^3}\left[\frac{1}{2}(ax+b)^2-2b(ax+b)+b^2\cdot ln\left|ax+b\right|\right]+C$

5. $\int \frac{dx}{x(ax+b)}=-\frac{1}{b}\cdot ln\left|\frac{ax+b}{x}\right|+C$

证明:被积函数 $f(x)=\frac{1}{x\cdot(ax+b)}$ 的定义域为 $\{x/x\neq -\frac{b}{a}\}$

设 $\frac{1}{x\cdot(ax+b)}=\frac{A}{x}+\frac{B}{ax+b}$,则 $1=A(ax+b)+Bx=(Aa+B)x+Ab$

$\therefore$ 有 $\begin{cases}Aa+B=0\\ Ab=1\end{cases} \Rightarrow \begin{cases}A=\frac{1}{b}\\ B=-\frac{a}{b}\end{cases}$

于是 $\int \frac{dx}{x(ax+b)}=\int [\frac{1}{bx}-\frac{a}{b\cdot(ax+b)}]dx=\frac{1}{b}\int \frac{1}{x}dx-\frac{a}{b}\int \frac{1}{ax+b}dx$

$$=\frac{1}{b}\int \frac{1}{x}dx-\frac{1}{b}\int \frac{1}{ax+b}d(ax+b)$$

$$=\frac{1}{b}\cdot ln\left|x\right|-\frac{1}{b}\cdot ln\left|ax+b\right|+C$$

$$=\frac{1}{b}\cdot ln\left|\frac{x}{ax+b}\right|+C$$

提示:$log_a b^{-1}=-log_a b$

$$=-\frac{1}{b}\cdot ln\left|\frac{ax+b}{x}\right|+C$$

6. $\int \frac{dx}{x^2\ (ax+b)} = -\frac{1}{bx} + \frac{a}{b^2} \cdot ln\left|\frac{ax+b}{x}\right| + C$

证明：被积函数 $f(x) = \frac{1}{x^2 \cdot (ax+b)}$ 的定义域为 $\{x \mid x \neq -\frac{b}{a}\}$

设 $\frac{1}{x^2 \cdot (ax+b)} = \frac{A}{x} + \frac{B}{x^2} + \frac{C}{ax+b}$，则 $1 = Ax(ax+b) + B(ax+b) + Cx^2$

即 $x^2(Aa + C) + x(Ab + aB) + Bb = 1$

$$\therefore\ 有 \begin{cases} Aa + C = 0 \\ Ab + aB = 0 \\ Bb = 1 \end{cases} \Rightarrow \begin{cases} A = -\frac{a}{b^2} \\ B = \frac{1}{b} \\ C = \frac{a^2}{b^2} \end{cases}$$

于是 $\int \frac{dx}{x^2\ (ax+b)} = -\frac{a}{b^2}\int \frac{1}{x}dx + \frac{1}{b}\int \frac{1}{x^2}dx + \frac{a^2}{b^2}\int \frac{1}{ax+b}dx$

$= -\frac{a}{b^2}\int \frac{1}{x}dx + \frac{1}{b}\int \frac{1}{x^2}dx + \frac{a}{b^2}\int \frac{1}{ax+b}d(ax+b)$

$= -\frac{a}{b^2} \cdot ln|\,x\,| - \frac{1}{bx} + \frac{a}{b^2} \cdot ln|\,ax+b\,| + C$

$= -\frac{1}{bx} + \frac{a}{b^2} \cdot ln\left|\frac{ax+b}{x}\right| + C$

7. $\int \frac{x}{(ax+b)^2}dx = \frac{1}{a^2}\left(ln|\,ax+b\,| + \frac{b}{ax+b}\right) + C$

证明：被积函数 $f(x) = \frac{x}{(ax+b)^2}$ 的定义域为 $\{x / x \neq -\frac{b}{a}\}$

设 $\frac{x}{(ax+b)^2} = \frac{A}{ax+b} + \frac{B}{(ax+b)^2}$，则 $x = A(ax+b) + B$

即 $x \cdot Aa + (Ab + B) = x$

$$\therefore\ 有 \begin{cases} Aa = 1 \\ Ab + B = 0 \end{cases} \Rightarrow \begin{cases} A = \frac{1}{a} \\ B = -\frac{b}{a} \end{cases}$$

于是 $\int \frac{x}{(ax+b)^2}dx = \frac{1}{a}\int \frac{1}{ax+b}dx - \frac{b}{a}\int \frac{1}{(ax+b)^2}dx$

$= \frac{1}{a^2}\int \frac{1}{ax+b}d(ax+b) - \frac{b}{a^2}\int \frac{1}{(ax+b)^2}d(ax+b)$

$= \frac{1}{a^2} \cdot ln|\,ax+b\,| + \frac{b}{a^2(ax+b)} + C$

$= \frac{1}{a^2}\left(ln|\,ax+b\,| + \frac{b}{ax+b}\right) + C$

8. $\int \frac{x^2}{(ax+b)^2}dx = \frac{1}{a^3}\left(ax+b-2b\cdot ln|ax+b|-\frac{b^2}{ax+b}\right)+C$

证明：被积函数 $f(x)=\frac{x^2}{(ax+b)^2}$ 的定义域为 $\{x\,|\,x\neq -\frac{b}{a}\}$

令 $ax+b=t\ \ (t\neq 0)$，则 $x=\frac{1}{a}(t-b)$，$dx=\frac{1}{a}dt$

$\therefore\ \ \frac{x^2}{(ax+b)^2}=\frac{(b-t)^2}{a^2t^2}=\frac{b^2+t^2-2bt}{a^2t^2}$

$\therefore\ \ \int \frac{x^2}{(ax+b)^2}dx=\int \frac{b^2+t^2-2bt}{a^3t^2}dt=\frac{b^2}{a^3}\int \frac{1}{t^2}dt+\frac{1}{a^3}\int dt-\frac{2b}{a^3}\int \frac{1}{t}dt$

$=-\frac{b^2}{a^3t}+\frac{1}{a^3}\cdot t-\frac{2b}{a^3}\cdot ln|t|+C$

$=\frac{1}{a^3}(t-2b\cdot ln|t|-\frac{b^2}{t})+C$

将 $t=ax+b$ 代入上式得：$\int \frac{x^2}{(ax+b)^2}dx=\frac{1}{a^3}\left(ax+b-2b\cdot ln|ax+b|-\frac{b^2}{ax+b}\right)+C$

9. $\int \frac{dx}{x(ax+b)^2}=\frac{1}{b(ax+b)}-\frac{1}{b^2}\cdot ln\left|\frac{ax+b}{x}\right|+C$

证明：被积函数 $f(x)=\frac{1}{x(ax+b)^2}$ 的定义域为 $\{x\,|\,x\neq -\frac{b}{a}\}$

设：$\frac{1}{x(ax+b)^2}=\frac{A}{x}+\frac{B}{ax+b}+\frac{D}{(ax+b)^2}$

则 $1=A(ax+b)^2+Bx(ax+b)+Dx$

$=Aa^2x^2+Ab^2+2Aabx+Bax^2+Bbx+Dx$

$=x^2(Aa^2+Ba)+x(2Aab+Bb+D)+Ab^2$

$\therefore$ 有 $\begin{cases}Aa^2+Ba=0\\ 2Aab+Bb+D=0\\ Ab^2=1\end{cases}\Rightarrow\begin{cases}A=\frac{1}{b^2}\\ B=-\frac{a}{b^2}\\ D=-\frac{a}{b}\end{cases}$

于是 $\int \frac{dx}{x(ax+b)}=\frac{1}{b^2}\int \frac{1}{x}dx-\frac{a}{b^2}\int \frac{1}{ax+b}dx-\frac{a}{b}\int \frac{1}{(ax+b)^2}dx$

$=\frac{1}{b^2}\cdot ln|x|-\frac{1}{b^2}\cdot ln|ax+b|+\frac{1}{b}\cdot\frac{1}{ax+b}+C$

$=\frac{1}{b(ax+b)}-\frac{1}{b^2}\cdot ln\left|\frac{ax+b}{x}\right|+C$

（二）含有 $\sqrt{ax+b}$ 的积分（10~18）

10. $\int\sqrt{ax+b}\,dx=\frac{2}{3a}\cdot\sqrt{(ax+b)^3}+C$

证明：$\int\sqrt{ax+b}\,dx=\frac{1}{a}\int(ax+b)^{\frac{1}{2}}d(ax+b)=\frac{1}{a}\cdot\frac{1}{1+\frac{1}{2}}\cdot(ax+b)^{\frac{1}{2}+1}+C$

$$=\frac{2}{3a}\cdot\sqrt{(ax+b)^3}+C$$

11. $\int x\sqrt{ax+b}\,dx=\frac{2}{15a^2}\cdot(3ax-2b)\cdot\sqrt{(ax+b)^3}+C$

证明：令 $\sqrt{ax+b}=t\quad(t\geq 0)$，则 $x=\frac{t^2-b}{a}$，$dx=\frac{2t}{a}dt$，$x\sqrt{ax+b}=\frac{t^2-b}{a}\cdot t$

$$\therefore\int x\sqrt{ax+b}\,dx=\int\frac{t^2-b}{a}\cdot t\cdot\frac{2t}{a}dt=\frac{2}{a^2}\int(t^4-bt^2)dt$$

$$=\frac{2}{5a^2}\int dt^5-\frac{2b}{3a^2}\int dt^3=\frac{2}{5a^2}\cdot t^5-\frac{2b}{3a^2}\cdot t^3+C$$

$$=\frac{2t^3}{15a^2}(3t^2-5b)+C$$

将 $t=\sqrt{ax+b}$ 代入上式得：$\int x\sqrt{ax+b}\,dx=\frac{2}{15a^2}[3(ax+b)-5b]\cdot\sqrt{(ax+b)^3}+C$

$$=\frac{2}{15a^2}\cdot(3ax-2b)\cdot\sqrt{(ax+b)^3}+C$$

12. $\int x^2\sqrt{ax+b}\,dx=\frac{2}{105a^3}\cdot(15a^2x^2-12abx+8b^2)\cdot\sqrt{(ax+b)^3}+C$

证明：令 $\sqrt{ax+b}=t\quad(t\geq 0)$，则 $x=\frac{t^2-b}{a}$，$dx=\frac{2t}{a}dt$，

$$x^2\sqrt{ax+b}=\frac{(t^2-b)^2}{a^2}\cdot t=\frac{t^5+b^2t-2bt^3}{a^2}$$

$$\therefore\int x^2\sqrt{ax+b}\,dx=\frac{2}{a^3}\int t\cdot(t^5+b^2t-2bt^3)dt$$

$$=\frac{2}{a^3}\int t^6\,dt-\frac{2b^2}{a^3}\int t^2\,dt-\frac{4b}{a^3}\int t^4\,dt$$

$$=\frac{2}{a^3}\cdot\frac{1}{1+6}\cdot t^{6+1}+\frac{2b^2}{a^3}\cdot\frac{1}{1+2}\cdot t^{1+2}-\frac{4b}{a^3}\cdot\frac{1}{1+4}\cdot t^{4+1}+C$$

$$=\frac{2}{7a^3}\cdot t^7+\frac{2b^2}{3a^3}\cdot t^3-\frac{4b}{5a^3}\cdot t^5+C$$

$$=\frac{2t^3}{105a^3}\cdot(15t^4+35b^2-42bt^2)+C$$

将 $t=\sqrt{ax+b}$ 代入上式得：

$$\int x^2\sqrt{ax+b}\,dx=\frac{2}{105a^3}\cdot\sqrt{(ax+b)^3}\left[15a^2x^2+15b^2+30abx+35b^2-42b\cdot(ax+b)\right]$$

$$=\frac{2}{105a^3}\cdot(15a^2x^2-12abx+8b^2)\cdot\sqrt{(ax+b)^3}+C$$

13. $\int \frac{x}{\sqrt{ax+b}}dx = \frac{2}{3a^2}\cdot(ax-2b)\cdot\sqrt{(ax+b)}+C$

证明：令$\sqrt{ax+b}=t \quad (t>0)$，则$x=\frac{t^2-b}{a}$ ， $dx=\frac{2t}{a}dt$ ，

$$\therefore \int \frac{x}{\sqrt{ax+b}}dx = \int \frac{t^2-b}{at}\cdot\frac{2t}{a}dt$$

$$= \frac{2}{a^2}\int t^2dt - \frac{2}{a^2}\int bdt$$

$$= \frac{2}{a^2}\cdot\frac{1}{1+2}\cdot t^{2+1} - \frac{2b}{a^2}\cdot t + C$$

$$= \frac{2}{3a^2}\cdot t^3 - \frac{2b}{a^2}\cdot t + C$$

将$t=\sqrt{ax+b}$代入上式得：$\int \frac{x}{\sqrt{ax+b}}dx = \frac{2}{3a^2}\cdot(ax+b)\cdot\sqrt{(ax+b)} - \frac{2b}{a^2}\cdot\sqrt{(ax+b)}+C$

$$= \frac{2}{3a^2}\cdot(ax-2b)\cdot\sqrt{(ax+b)}+C$$

14. $\int \frac{x^2}{\sqrt{ax+b}}dx = \frac{2}{15a^3}\cdot(3a^2x^2-4abx+8b^2)\cdot\sqrt{(ax+b)}+C$

证明：令$\sqrt{ax+b}=t \quad (t>0)$，则$x=\frac{t^2-b}{a}$ ， $dx=\frac{2t}{a}dt$ ，

$$\therefore \int \frac{x^2}{\sqrt{ax+b}}dx = \int (\frac{t^2-b}{a})^2\cdot\frac{1}{t}\cdot\frac{2t}{a}dt$$

$$= \frac{2}{a^3}\int (t^4+b^2-2bt^2)dt$$

$$= \frac{2}{a^3}\int t^4dt + \frac{2}{a^3}\int b^2dt - \frac{4b}{a^3}\int t^2dt$$

$$= \frac{2}{a^3}(\frac{1}{5}t^5 + b^2t - \frac{2b}{3}t^3) + C$$

$$= \frac{2t}{15a^3}\cdot(3t^4+15b^2-10bt^2)+C$$

将$t=\sqrt{ax+b}$代入上式得：

$$\int \frac{x^2}{\sqrt{ax+b}}dx = \frac{2}{15a^3}\cdot\sqrt{(ax+b)}\cdot\left[3(a^2x^2+b^2+2abx)+15b^2-10b\cdot(ax+b)\right]\cdot\sqrt{(ax+b)}+C$$

$$= \frac{2}{15a^3}\cdot(3a^2x^2-4abx+8b^2)\cdot\sqrt{(ax+b)}+C$$

15. $\int \frac{dx}{x\sqrt{ax+b}} = \begin{cases} \frac{1}{\sqrt{b}} \cdot ln\left|\frac{\sqrt{ax+b}-\sqrt{b}}{\sqrt{ax+b}+\sqrt{b}}\right| + C & (b>0) \\ \frac{2}{\sqrt{-b}} \cdot arctan\sqrt{\frac{ax+b}{-b}} + C & (b<0) \end{cases}$

证明：令$\sqrt{ax+b} = t \quad (t>0)$，则$x = \frac{t^2-b}{a}$ ， $dx = \frac{2t}{a}dt$ ，

$$\therefore \int \frac{dx}{x\sqrt{ax+b}} = \int \frac{1}{\frac{t^2-b}{a} \cdot t} \cdot \frac{2t}{a} dt$$

$$= \int \frac{2}{t^2-b} dt$$

1.当b > 0时，$\int \frac{2}{t^2-b} dt = 2\int \frac{1}{t^2-(\sqrt{b})^2} dt$

公式 21：$\int \frac{dx}{x^2-a^2} = \frac{1}{2a} \cdot ln\left|\frac{x-a}{x+a}\right| + C$

$$= \frac{1}{\sqrt{b}} \cdot ln\left|\frac{t-\sqrt{b}}{t+\sqrt{b}}\right| + C$$

将$t = \sqrt{ax+b}$代入上式得：$\int \frac{dx}{x\sqrt{ax+b}} = \frac{1}{\sqrt{b}} \cdot ln\left|\frac{\sqrt{ax+b}-\sqrt{b}}{\sqrt{ax+b}+\sqrt{b}}\right| + C$

2.当$b<0$时，$\int \frac{2}{t^2-b} dt = 2\int \frac{1}{t^2+(\sqrt{-b})^2} dt$

公式 19：$\int \frac{dx}{x^2+a^2} = \frac{1}{a} \cdot arctan\ \frac{x}{a} + C$

$$= \frac{2}{\sqrt{-b}} \cdot arctan \frac{\mathrm{t}}{\sqrt{-b}} + C$$

将$t = \sqrt{ax+b}$代入上式得：$\int \frac{dx}{x\sqrt{ax+b}} = \frac{2}{\sqrt{-b}} \cdot arctan\sqrt{\frac{ax+b}{-b}} + C$

综合讨论1, 2得：$\int \frac{dx}{x\sqrt{ax+b}} = \begin{cases} \frac{1}{\sqrt{b}} \cdot ln\left|\frac{\sqrt{ax+b}-\sqrt{b}}{\sqrt{ax+b}+\sqrt{b}}\right| + C & (b>0) \\ \frac{2}{\sqrt{-b}} \cdot arctan\sqrt{\frac{ax+b}{-b}} + C & (b>0) \end{cases}$

16. $\int \frac{dx}{x^2\sqrt{ax+b}} = -\frac{\sqrt{ax+b}}{bx} - \frac{a}{2b}\int \frac{dx}{x\sqrt{ax+b}}$

证明：设 $\frac{1}{x^2\cdot\sqrt{ax+b}} = \frac{\mathrm{A}}{x\sqrt{ax+b}} + \frac{B\sqrt{ax+b}}{x^2}$，则 $1 = \mathrm{A}x + \mathrm{B}(ax+b)$

$\therefore$ 有 $\begin{cases} A + Ba = 0 \\ Bb = 1 \end{cases} \Rightarrow \begin{cases} \mathrm{A} = -\frac{a}{b} \\ \mathrm{B} = \frac{1}{b} \end{cases}$

于是 $\int \frac{dx}{x^2\sqrt{ax+b}} = -\frac{a}{b}\int \frac{1}{x\sqrt{ax+b}}dx + \frac{1}{b}\int \frac{\sqrt{ax+b}}{x^2}dx$

$$= -\frac{a}{b}\int \frac{1}{x\sqrt{ax+b}}dx - \frac{1}{b}\int \sqrt{ax+b}\, d\frac{1}{x}$$

$$= -\frac{a}{b}\int \frac{1}{x\sqrt{ax+b}}dx - \frac{\sqrt{ax+b}}{bx} + \frac{1}{b}\int \frac{1}{x} d\sqrt{ax+b}$$

$$= -\frac{a}{b}\int \frac{1}{x\sqrt{ax+b}}dx - \frac{\sqrt{ax+b}}{bx} + \frac{1}{b}\int \frac{1}{x}\cdot\frac{a}{2}(ax+b)^{-\frac{1}{2}}dx$$

$$= -\frac{a}{b}\int \frac{1}{x\sqrt{ax+b}}dx - \frac{\sqrt{ax+b}}{bx} + \frac{a}{2b}\int \frac{1}{x\sqrt{ax+b}}dx$$

$$= -\frac{\sqrt{ax+b}}{bx} - \frac{a}{2b}\int \frac{dx}{x\sqrt{ax+b}}$$

17. $\int \frac{\sqrt{ax+b}}{x}dx = 2\sqrt{ax+b} + b\int \frac{dx}{x\sqrt{ax+b}}$

证明：令 $\sqrt{ax+b} = t \quad (t \geq 0)$，则 $x = \frac{t^2-b}{a}$ ， $dx = \frac{2t}{a}dt$

$\therefore \int \frac{\sqrt{ax+b}}{x}dx = \int \frac{at}{t^2-b}\cdot\frac{2t}{a}dt = 2\int \frac{t^2}{t^2-b}dt$

$$= 2\int \frac{t^2-b^2+b^2}{t^2-b}dt = 2\int dt + 2b\int \frac{1}{t^2-b}dt$$

$$= 2t + 2b\int \frac{1}{t^2-b}dt$$

$\because b$ 取值为 R，符号可正可负 $\therefore \int \frac{1}{t^2-b}dt$ 不能明确积分

$\therefore \int \frac{\sqrt{ax+b}}{x}dx = 2t + 2b\int \frac{1}{t^2-b}dt$

$$= 2t + 2b\int \frac{1}{t^2-b}\cdot\frac{a}{2t}dx$$

将 $t = \sqrt{ax+b}$ 代入上式得：$\int \frac{\sqrt{ax+b}}{x}dx = 2\sqrt{(ax+b)} + 2b\int \frac{1}{ax+b-b}\cdot\frac{a}{2\sqrt{ax+b}}dx$

$$= 2\sqrt{ax+b} + b\int \frac{dx}{x\sqrt{ax+b}}$$

18. $\int \frac{\sqrt{ax+b}}{x^2}dx = -\frac{\sqrt{ax+b}}{x} + \frac{a}{2}\int \frac{dx}{x\sqrt{ax+b}}$

证明：$\int \frac{\sqrt{ax+b}}{x^2}dx = -\int \sqrt{ax+b}\, d\frac{1}{x}$

$$= -\frac{\sqrt{ax+b}}{x} + \int \frac{1}{x} d\sqrt{ax+b}$$

$$= -\frac{\sqrt{ax+b}}{x} + \int \frac{1}{x} \cdot (ax+b)^{-\frac{1}{2}} \cdot \frac{a}{2} dx$$

$$= -\frac{\sqrt{ax+b}}{x} + \frac{a}{2}\int \frac{dx}{x\sqrt{ax+b}}$$

（三）含有 $x^2 \pm a^2$ 的积分（19~21）

19. $\int \frac{dx}{x^2+a^2} = \frac{1}{a} \cdot arctan\frac{x}{a} + C$

证明：令 $x = a \cdot tant \quad (-\frac{\pi}{2} < t < \frac{\pi}{2})$，则 $dx = d(a \cdot tant) = a \cdot sec^2 t\, dt$

$$\frac{1}{x^2+a^2} = \frac{dx}{a^2 \cdot (1+tan^2 t)} = \frac{1}{a^2 sec^2 t}$$

$$\therefore \int \frac{dx}{x^2+a^2} = \int \frac{1}{a^2 sec^2 t} \cdot a \cdot sec^2 t\, dt$$

$$= \frac{1}{a}\int dt$$

$$= \frac{1}{a} \cdot t + C$$

$\because x = a \cdot tant \qquad \therefore t = arctan\frac{x}{a}$

将 $t = arctan\frac{x}{a}$ 代入上式得：$\int \frac{dx}{x^2+a^2} = \frac{1}{a} \cdot arctan\frac{x}{a} + C$

20. $\int \frac{dx}{(x^2+a^2)^n} = \frac{x}{2(n-1)\cdot a^2\cdot(x^2+a^2)^{n-1}} + \frac{2n-3}{2(n-1)\cdot a^2}\int\frac{dx}{(x^2+a^2)^{n-1}}$

证明：$\int \frac{dx}{(x^2+a^2)^n} = \frac{x}{(x^2+a^2)^n} - \int x\, d\frac{1}{(x^2+a^2)^n}$

$$= \frac{x}{(x^2+a^2)^n} - \int x\cdot(-n)\cdot(x^2+a^2)^{-n-1}\cdot 2x\, dx$$

$$= \frac{x}{(x^2+a^2)^n} + 2n\int\frac{x^2}{(x^2+a^2)^{n+1}}dx$$

$$= \frac{x}{(x^2+a^2)^n} + 2n\int\frac{x^2+a^2-a^2}{(x^2+a^2)^{n+1}}dx$$

$$= \frac{x}{(x^2+a^2)^n} + 2n\int\frac{1}{(x^2+a^2)^n}dx - 2na^2\int\frac{1}{(x^2+a^2)^{n+1}}dx$$

移项并整理得：$(1-2n)\int\frac{dx}{(x^2+a^2)^n} = \frac{x}{(x^2+a^2)^n} - 2na^2\int\frac{1}{(x^2+a^2)^{n+1}}dx$

$$\therefore \int\frac{1}{(x^2+a^2)^{n+1}}dx = \frac{1}{2na^2}\left[\frac{x}{(x^2+a^2)^n} + (2n-1)\int\frac{dx}{(x^2+a^2)^n}\right]$$

令$n+1=n$，则$\int\frac{dx}{(x^2+a^2)^n} = \frac{1}{2(n-1)\cdot a^2}\left[\frac{x}{(x^2+a^2)^{n-1}} + (2n-3)\int\frac{dx}{(x^2+a^2)^{n-1}}\right]$

$$= \frac{x}{2(n-1)\cdot a^2\cdot(x^2+a^2)^{n-1}} + \frac{2n-3}{2(n-1)\cdot a^2}\int\frac{dx}{(x^2+a^2)^{n-1}}$$

21. $\int\frac{dx}{x^2-a^2} = \frac{1}{2a}\cdot ln\left|\frac{x-a}{x+a}\right| + C$

证明：$\int\frac{dx}{x^2-a^2} = \frac{1}{2a}\int[\frac{1}{x-a}-\frac{1}{x+a}]\,dx$

$$= \frac{1}{2a}\int\frac{1}{x-a}dx - \frac{1}{2a}\int\frac{1}{x+a}dx$$

$$= \frac{1}{2a}\cdot ln|x-a| - \frac{1}{2a}\cdot ln|x+a| + C$$

$$= \frac{1}{2a}\cdot ln\left|\frac{x-a}{x+a}\right| + C$$

（四）含有 $ax^2+b\ (a>0)$ 的积分（22~28）

22. $$\int\frac{dx}{ax^2+b}=\begin{cases}\dfrac{1}{\sqrt{ab}}\cdot arctan\sqrt{\dfrac{a}{b}}\cdot x+C & (b>0)\\ \dfrac{1}{2\sqrt{-ab}}\cdot ln\left|\dfrac{\sqrt{a}\cdot x-\sqrt{-b}}{\sqrt{a}\cdot x+\sqrt{-b}}\right|+C & (b<0)\end{cases}\qquad (a>0)$$

证明：

$$1.当b>0时,\frac{1}{ax^2+b}=\frac{1}{x^2+\frac{b}{a}}\cdot\frac{1}{a}=\frac{1}{x^2+(\sqrt{\frac{b}{a}})^2}\cdot\frac{1}{a}$$

$$\therefore\ \int\frac{dx}{ax^2+b}=\frac{1}{a}\int\frac{1}{x^2+(\sqrt{\frac{b}{a}})^2}dx$$

$$=\frac{1}{a}\cdot\sqrt{\frac{a}{b}}\cdot arctan\sqrt{\frac{a}{b}}\cdot x+\mathrm{C}$$

$$=\frac{1}{\sqrt{ab}}\cdot arctan\sqrt{\frac{a}{b}}\cdot x+C$$

$$2.当b<0时,\frac{1}{ax^2+b}=\frac{1}{x^2-(-\frac{b}{a})}\cdot\frac{1}{a}=\frac{1}{x^2-(\sqrt{-\frac{b}{a}})^2}\cdot\frac{1}{a}$$

$$\therefore\ \int\frac{dx}{ax^2+b}=\frac{1}{a}\int\frac{1}{x^2-(\sqrt{-\frac{b}{a}})^2}dx$$

$$=\frac{1}{2\sqrt{\frac{-b}{a}}}\cdot\frac{1}{a}\cdot ln\left|\frac{x-\sqrt{\frac{-b}{a}}}{x+\sqrt{\frac{-b}{a}}}\right|+C$$

$$=\frac{1}{2\sqrt{-ab}}\cdot ln\left|\frac{\sqrt{a}\cdot x-\sqrt{-b}}{\sqrt{a}\cdot x+\sqrt{-b}}\right|+C$$

$$综合讨论1,2得:\int\frac{dx}{ax^2+b}=\begin{cases}\dfrac{1}{\sqrt{ab}}\cdot arctan\sqrt{\dfrac{a}{b}}\cdot x+C & (b>0)\\ \dfrac{1}{2\sqrt{-ab}}\cdot ln\left|\dfrac{\sqrt{a}\cdot x-\sqrt{-b}}{\sqrt{a}\cdot x+\sqrt{-b}}\right|+C & (b<0)\end{cases}$$

23. $$\int\frac{x}{ax^2+b}dx=\frac{1}{2a}\cdot ln\left|ax^2+b\right|+C\qquad (a>0)$$

$$证明:\int\frac{x}{ax^2+b}dx=\frac{1}{2}\int\frac{1}{ax^2+b}dx^2$$

$$=\frac{1}{2a}\int\frac{1}{ax^2+b}d(ax^2+b)$$

$$=\frac{1}{2a}\cdot ln\left|ax^2+b\right|+C$$

24. $\int \frac{x^2}{ax^2+b}dx = \frac{x}{a} - \frac{b}{a}\int \frac{dx}{ax^2+b} \qquad (a>0)$

证明：$\int \frac{x^2}{ax^2+b}dx = \frac{b}{a}\int \frac{ax^2}{ax^2+b}\cdot\frac{1}{b}dx$

$$= \frac{b}{a}\int (\frac{1}{b} - \frac{1}{ax^2+b})dx$$

$$= \frac{b}{a}\int \frac{1}{b}dx - \frac{b}{a}\int \frac{1}{ax^2+b}dx$$

$$= \frac{x}{a} - \frac{b}{a}\int \frac{dx}{ax^2+b}$$

25. $\int \frac{dx}{x(ax^2+b)} = \frac{1}{2b}\cdot ln\frac{x^2}{|ax^2+b|} + \mathrm{C} \qquad (a>0)$

证明：$\int \frac{dx}{x(ax^2+b)} = \int \frac{x}{x^2(ax^2+b)}dx$

$$= \frac{1}{2}\int \frac{1}{x^2(ax^2+b)}dx^2$$

设：$\frac{1}{x^2(ax^2+b)} = \frac{A}{x^2} + \frac{B}{ax^2+b}$

则 $1 = A(ax^2+b) + Bx^2 = x^2(Aa+B) + Ab$

$\therefore$ 有 $\begin{cases} Aa+B=0 \\ Ab=1 \end{cases} \Rightarrow \begin{cases} A=\frac{1}{b} \\ B=-\frac{a}{b} \end{cases}$

于是 $\int \frac{dx}{x(ax^2+b)} = \frac{1}{2}\int [\frac{1}{bx^2} - \frac{a}{b(ax^2+b)}]dx^2$

$$= \frac{1}{2b}\int \frac{1}{x^2}dx^2 - \frac{a}{2b}\int \frac{1}{ax^2+b}dx^2$$

$$= \frac{1}{2b}\int \frac{1}{x^2}dx^2 - \frac{1}{2b}\int \frac{1}{ax^2+b}d(ax^2+b)$$

$$= \frac{1}{2b}\cdot ln|x^2| - \frac{1}{2b}\cdot ln|ax^2+b| + C$$

$$= \frac{1}{2b}\cdot ln\frac{x^2}{|ax^2+b|} + \mathrm{C}$$

26. $\int \frac{dx}{x^2(ax^2+b)} = -\frac{1}{bx} - \frac{a}{b}\int \frac{dx}{ax^2+b} \qquad (a>0)$

证明：设： $\frac{1}{x^2(ax^2+b)} = \frac{A}{x^2} + \frac{B}{ax^2+b}$

则 $1 = A(ax^2+b) + Bx^2 = x^2(Aa+B) + Ab$

$\therefore$ 有 $\begin{cases} Aa+B=0 \\ Ab=1 \end{cases} \Rightarrow \begin{cases} A=\frac{1}{b} \\ B=-\frac{a}{b} \end{cases}$

于是 $\int \frac{dx}{x^2(ax^2+b)} = \int [\frac{1}{bx^2} - \frac{a}{b(ax^2+b)}]dx$

$$= \frac{1}{b}\int \frac{1}{x^2}dx - \frac{a}{b}\int \frac{1}{ax^2+b}dx$$

$$= -\frac{1}{bx} - \frac{a}{b}\int \frac{dx}{ax^2+b}$$

27. $\int \frac{dx}{x^3(ax^2+b)} = \frac{a}{2b^2} ln\frac{|ax^2+b|}{x^2} - \frac{1}{2bx^2} + C \qquad (a>0)$

证明:$\int \frac{dx}{x^3(ax^2+b)} = \int \frac{x}{x^4(ax^2+b)}dx$

$$= \frac{1}{2}\int \frac{1}{x^4(ax^2+b)}dx^2$$

设： $\frac{1}{x^4(ax^2+b)} = \frac{A}{x^2} + \frac{B}{x^4} + \frac{C}{ax^2+b}$

则 $1 = Ax^2(ax^2+b) + B(ax^2+b) + Cx^4$

$$= (Aa+C)x^4 + (Ab+Ba)x^2 + Bb$$

$\therefore$ 有 $\begin{cases} Aa+C=0 \\ Ab+Ba=0 \\ Bb=1 \end{cases} \Rightarrow \begin{cases} B=\frac{1}{b} \\ A=-\frac{a}{b^2} \\ C=\frac{a^2}{b^2} \end{cases}$

于是 $\int \frac{dx}{x^3(ax^2+b)} = -\frac{a}{2b^2}\int \frac{1}{x^2}dx^2 + \frac{1}{2b}\int \frac{1}{x^4}dx^2 + \frac{a^2}{2b^2}\int \frac{1}{ax^2+b}dx^2$

$$= -\frac{a}{2b^2}\cdot ln|x^2| - \frac{1}{2bx^2} + \frac{a}{2b^2}\cdot ln|ax^2+b| + C$$

$$= \frac{a}{2b^2} ln\frac{|ax^2+b|}{x^2} - \frac{1}{2bx^2} + C$$

28. $\int \frac{dx}{(ax^2+b)^2} = \frac{x}{2b(ax^2+b)} + \frac{1}{2b}\int \frac{dx}{ax^2+b}$ $\qquad (a>0)$

证明：$\int \frac{dx}{(ax^2+b)^2} = -\int \frac{1}{2ax} d\frac{1}{ax^2+b} = -\frac{1}{2ax}\cdot\frac{1}{ax^2+b} + \int \frac{1}{ax^2+b} d\frac{1}{2ax}$

$= -\frac{1}{2ax}\cdot\frac{1}{ax^2+b} - \int \frac{1}{ax^2+b}\cdot\frac{1}{2ax^2}dx$

设：$\frac{1}{2ax^2(ax^2+b)} = \frac{A}{2ax^2} + \frac{B}{ax^2+b}$，则 $1 = A(ax^2+b) + 2Bax^2 = (Aa+2Ba)x^2 + Ab$

$$\therefore \text{有} \begin{cases} Aa+2Ba=0 \\ Ab=1 \end{cases} \Rightarrow \begin{cases} A=\frac{1}{b} \\ B=-\frac{1}{2b} \end{cases}$$

于是 上式 $= -\frac{1}{2ax(ax^2+b)} - \int (\frac{1}{2abx^2} - \frac{1}{2b(ax^2+b)})dx$

$= -\frac{1}{2ax(ax^2+b)} - \frac{1}{2ab}\int \frac{1}{x^2}dx + \frac{1}{2b}\int \frac{1}{2b(ax^2+b)}dx$

$= -\frac{1}{2ax(ax^2+b)} + \frac{1}{2abx} + \frac{1}{2b}\int \frac{1}{2b(ax^2+b)}dx = \frac{ax^2+b-b}{2abx(ax^2+b)} + \frac{1}{2b}\int \frac{1}{2b(ax^2+b)}dx$

$= \frac{x}{2b(ax^2+b)} + \frac{1}{2b}\int \frac{dx}{ax^2+b}$

（五）含有 $ax^2+bx+c\ (a>0)$ 的积分（29~30）

$$29.\ \int \frac{dx}{ax^2+bx+c} = \begin{cases} \frac{2}{\sqrt{4ac-b^2}}\cdot arctan\frac{2ax+b}{\sqrt{4ac-b^2}} + C & (b^2<4ac) \\ \frac{1}{\sqrt{b^2-4ac}}\cdot ln\left|\frac{2ax+b-\sqrt{b^2-4ac}}{2ax+b+\sqrt{b^2-4ac}}\right| + C & (b^2>4ac) \end{cases} \qquad (a>0)$$

证明：$\because\ ax^2+bx+c = \frac{1}{4a}\left[(2ax+b)^2 + (4ac-b^2)\right]$

$\therefore \int \frac{dx}{ax^2+bx+c} = 4a\int \frac{1}{(2ax+b)^2+(4ac-b^2)}dx$

1.当 $b^2<4ac$ 时，$\int \frac{dx}{ax^2+bx+c} = 4a\int \frac{1}{(2ax+b)^2+(\sqrt{4ac-b^2})^2}dx$

> 公式 19：$\int \frac{dx}{x^2+a^2} = \frac{1}{a}\cdot arctan\frac{x}{a} + C$

$= \frac{4a}{2a}\int \frac{1}{(2ax+b)^2+(\sqrt{4ac-b^2})^2}d(2ax+b)$

$= \frac{2}{\sqrt{4ac-b^2}}\cdot arctan\frac{2ax+b}{\sqrt{4ac-b^2}} + C$

2.当 $b^2>4ac$ 时，$\int \frac{dx}{ax^2+bx+c} = 4a\int \frac{1}{(2ax+b)^2+(4ac-b^2)}dx$

$= 4a\int \frac{1}{(2ax+b)^2-(b^2-4ac)}dx$

> 公式 21：$\int \frac{dx}{x^2-a^2} = \frac{1}{2a}\cdot ln\left|\frac{x-a}{x+a}\right| + C$

$= \frac{4a}{2a}\int \frac{1}{(2ax+b)^2-(\sqrt{b^2-4ac})^2}d(2ax+b)$

$= \frac{1}{\sqrt{b^2-4ac}}\cdot ln\left|\frac{2ax+b-\sqrt{b^2-4ac}}{2ax+b+\sqrt{b^2-4ac}}\right| + C$

$$\text{综合讨论1,2得：} \int \frac{dx}{ax^2+bx+c} = \begin{cases} \frac{2}{\sqrt{4ac-b^2}}\cdot arctan\frac{2ax+b}{\sqrt{4ac-b^2}} + C & (b^2<4ac) \\ \frac{1}{\sqrt{b^2-4ac}}\cdot ln\left|\frac{2ax+b-\sqrt{b^2-4ac}}{2ax+b+\sqrt{b^2-4ac}}\right| + C & (b^2>4ac) \end{cases}$$

30. $\int \frac{x}{ax^2+bx+c}dx = \frac{1}{2a}\cdot ln\left|ax^2+bx+c\right| - \frac{b}{2a}\int \frac{dx}{ax^2+bx+c} \qquad (a>0)$

证明: $\int \frac{x}{ax^2+bx+c}dx = \int \frac{1}{2a}\cdot\frac{2ax+b-b}{ax^2+bx+c}dx$

$$= \frac{1}{2a}\int \frac{2ax+b}{ax^2+bx+c}dx + \frac{1}{2a}\int \frac{-b}{ax^2+bx+c}dx$$

$$= \frac{1}{2a}\int \frac{1}{ax^2+bx+c}d(ax^2+bx+c) - \frac{b}{2a}\int \frac{1}{ax^2+bx+c}dx$$

$$= \frac{1}{2a}\cdot ln\left|ax^2+bx+c\right| - \frac{b}{2a}\int \frac{dx}{ax^2+bx+c}$$

（六）含有 $\sqrt{x^2+a^2}$ $(a>0)$ 的积分（31~44）

31. $\int \frac{dx}{\sqrt{x^2+a^2}} = arsh\frac{x}{a} + C_1 = ln(x+\sqrt{x^2+a^2}) + \mathrm{C} \qquad (a>0)$

证明: 被积函数 $f(x) = \frac{1}{\sqrt{x^2+a^2}}$ 的定义域为 $\{x \mid x\in R\}$

可令 $x = a\,tant \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$, 则 $dx = d(a\,tant) = a\,sec^2 t dt$, $\sqrt{x^2+a^2} = |a\,sect|$

$\because -\frac{\pi}{2}<t<\frac{\pi}{2}, sect = \frac{1}{cost}>0, \therefore \sqrt{x^2+a^2} = a\,sect$

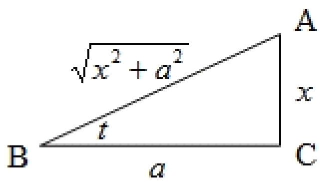
$\therefore \int \frac{dx}{\sqrt{x^2+a^2}} = \int \frac{1}{a\,sect}\cdot a\,sec^2 t\,dt$ 　　公式87: $\int sectdt = ln|sect+tant|+C$

$$= \int sect\,dt$$

$$= ln\left|sect+tant\right| + C_2$$

在RtΔABC中，设$\angle \mathrm{B} = t$, $|BC| = a$,则 $|\mathrm{AC}| = x$, $|\mathrm{AB}| = \sqrt{x^2+a^2}$

$\therefore sect = \frac{1}{cost} = \frac{\sqrt{x^2+a^2}}{a}$, $tant = \frac{x}{a}$



$\therefore \int \frac{dx}{\sqrt{x^2+a^2}} = ln\left|sect+tant\right| + C_2$

$$= ln\left|\frac{\sqrt{x^2+a^2}+x}{a}\right| + C_2$$

$$= ln\left|\sqrt{x^2+a^2}+x\right| - lna + C_2$$

$$= ln\left|\sqrt{x^2+a^2}+x\right| + C_3$$

$\because \sqrt{x^2+a^2}+x>0$

$\therefore \int \frac{dx}{\sqrt{x^2+a^2}} = ln(x+\sqrt{x^2+a^2}) + \mathrm{C}$

32. $\int\frac{dx}{\sqrt{(x^2+a^2)^3}}=\frac{x}{a^2\sqrt{x^2+a^2}}+C \qquad (a>0)$

证明:被积函数 $f(x)=\frac{1}{\sqrt{(x^2+a^2)^3}}$的定义域为$\{x|\ x\in R\}$

可令$x=a\,tant \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$, 则$dx=d(a\,tant)=a\,sec^2tdt$, $\sqrt{(x^2+a^2)^3}=|\,a^3\ sec^3t\,|$

$\because\ -\frac{\pi}{2}<t<\frac{\pi}{2}, sect=\frac{1}{cost}>0$, $\therefore\ \sqrt{(x^2+a^2)^3}=a^3\ sec^3t$

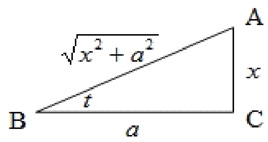
$$\therefore\ \int\frac{dx}{\sqrt{(x^2+a^2)^3}}=\int\frac{1}{a^3\ sec^3t}\cdot a\,sec^2t\,dt=\frac{1}{a^2}\int\frac{1}{sect}dt$$

$$=\frac{1}{a^2}\int\cos tdt=\frac{1}{a^2}sint+C$$

在Rt$\varDelta ABC$中，设$\angle\mathrm{B}=t$, $|\,BC\,|=a$,则$|\,\mathrm{AC}\,|=x$, $|\,\mathrm{AB}\,|=\sqrt{x^2+a^2}$

$$\therefore\ \mathrm{sint}=\frac{|\,\mathrm{AC}\,|}{|\,\mathrm{AB}\,|}=\frac{x}{\sqrt{x^2+a^2}}$$

$$\therefore\ \int\frac{dx}{\sqrt{(x^2+a^2)^3}}=\frac{1}{a^2}\cdot sint+C=\frac{x}{a^2\sqrt{x^2+a^2}}+C$$



33. $\int\frac{x}{\sqrt{x^2+a^2}}dx=\sqrt{x^2+a^2}+C \qquad (a>0)$

证明:令$\sqrt{x^2+a^2}=t \quad (t>0)$, 则$x=\sqrt{t^2-a^2}$

$$\therefore\ dx=\frac{1}{2}(t^2-a^2)^{-\frac{1}{2}}\cdot 2tdt=\frac{t}{\sqrt{t^2-a^2}}dt$$

$$\therefore\ \int\frac{x}{\sqrt{x^2+a^2}}dx=\int\frac{\sqrt{t^2-a^2}}{t}\cdot\frac{t}{\sqrt{t^2-a^2}}dt$$

$$=\int dt=t+C$$

将$t=\sqrt{x^2+a^2}$代入上式得:$\int\frac{x}{\sqrt{x^2+a^2}}dx=\sqrt{x^2+a^2}+C$

34. $\int\frac{x}{\sqrt{(x^2+a^2)^3}}dx=-\frac{1}{\sqrt{x^2+a^2}}+C \qquad (a>0)$

证明:$\int\frac{x}{\sqrt{(x^2+a^2)^3}}dx=\int x\cdot(x^2+a^2)^{-\frac{3}{2}}dx=\frac{1}{2}\int(x^2+a^2)^{-\frac{3}{2}}dx^2$

$$=\frac{1}{2}\int(x^2+a^2)^{-\frac{3}{2}}d(x^2+a^2)$$

$$=\frac{1}{2}\times\frac{1}{1-\frac{3}{2}}\cdot(x^2+a^2)^{1-\frac{3}{2}}+C$$

$$=-\frac{1}{\sqrt{x^2+a^2}}+C$$

35. $\int \frac{x^2}{\sqrt{x^2+a^2}}dx = \frac{x}{2}\cdot\sqrt{x^2+a^2} - \frac{a^2}{2}ln(x+\sqrt{x^2+a^2}) + C \qquad (a>0)$

证明：$\int \frac{x^2}{\sqrt{x^2+a^2}}dx = \int \frac{x^2+a^2-a^2}{\sqrt{x^2+a^2}}dx$

$$= \int \sqrt{x^2+a^2}\,dx - a^2\int \frac{1}{\sqrt{x^2+a^2}}dx$$

$\because \int \sqrt{x^2+a^2}\,dx = \frac{x}{2}\cdot\sqrt{x^2+a^2} + \frac{a^2}{2}\cdot ln(x+\sqrt{x^2+a^2}) + C \qquad$ (公式39)

$\int \frac{1}{\sqrt{x^2+a^2}}dx = ln(x+\sqrt{x^2+a^2}) + C \qquad$ (公式31)

$\therefore \int \frac{x^2}{\sqrt{x^2+a^2}}dx = \frac{x}{2}\cdot\sqrt{x^2+a^2} + \frac{a^2}{2}ln(x+\sqrt{x^2+a^2}) - a^2\cdot ln(x+\sqrt{x^2+a^2}) + C$

$$= \frac{x}{2}\cdot\sqrt{x^2+a^2} - \frac{a^2}{2}\cdot ln(x+\sqrt{x^2+a^2}) + C$$

36. $\int \frac{x^2}{\sqrt{(x^2+a^2)^3}}dx = -\frac{x}{\sqrt{x^2+a^2}} + ln(x+\sqrt{x^2+a^2}) + C \qquad (a>0)$

证明：被积函数 $f(x) = \frac{x^2}{\sqrt{(x^2+a^2)^3}}$ 的定义域为$\{x|\ x\in R\}$

可令$x = a\,tant \quad (-\frac{\pi}{2} < t < \frac{\pi}{2})$，则$dx = d(a\,tant) = a\,sec^2 tdt$，$\frac{x^2}{\sqrt{(x^2+a^2)^3}} = \frac{a^2 tan^2 t}{|a^3 sec^3 t|}$

$\because -\frac{\pi}{2} < t < \frac{\pi}{2}$, $sect = \frac{1}{cost} > 0$，$\therefore \frac{x^2}{\sqrt{(x^2+a^2)^3}} = \frac{tan^2 t}{a\,sec^3 t}$

$\therefore \int \frac{x^2}{\sqrt{(x^2+a^2)^3}}dx = \int \frac{tan^2 t}{a\,sec^3 t}\cdot a\,sec^2 tdt = \int \frac{tan^2 t}{sect}dt = \int \frac{sec^2 t - 1}{sect}dt$

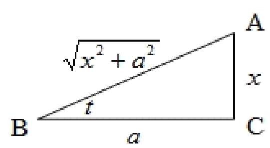
$$= \int sectdt - \int \frac{1}{sect}dt = \int sectdt - \int \cos tdt$$

$$= ln|\,sect + tant\,| - sint + C_1$$

公式 87: $\int \sec t\,dt = ln|\,sect + tant\,| + C$

在RtΔABC中，设$\angle B = t$，$|BC| = a$，则$|AC| = x$，$|AB| = \sqrt{x^2+a^2}$

$\therefore sint = \frac{x}{\sqrt{x^2+a^2}}$, $tant = \frac{x}{a}$, $sect = \frac{1}{cost} = \frac{\sqrt{x^2+a^2}}{a}$



$\therefore \int \frac{x^2}{\sqrt{(x^2+a^2)^3}}dx = ln|\,sect + tant\,| - sint + C_1$

$$= ln\left|\frac{\sqrt{x^2+a^2}+x}{a}\right| - \frac{x}{\sqrt{x^2+a^2}} + C_1$$

$$= ln\left|\sqrt{x^2+a^2}+x\right| - \frac{x}{\sqrt{x^2+a^2}} - lna + C_1$$

$\because \sqrt{x^2+a^2} + x > 0$

$\therefore \int \frac{x^2}{\sqrt{(x^2+a^2)^3}}dx = -\frac{x}{\sqrt{x^2+a^2}} + ln(x+\sqrt{x^2+a^2}) + C$

37. $\int \frac{dx}{x\cdot\sqrt{x^2+a^2}}=\frac{1}{a}\cdot ln\frac{\sqrt{x^2+a^2}-a}{|x|}+C \qquad (a>0)$

证明：令$\sqrt{x^2+a^2}=t \quad (t>0)$，则$x=\sqrt{t^2-a^2}$

$$\therefore\ dx=\frac{1}{2}(t^2-a^2)^{-\frac{1}{2}}\cdot 2tdt=\frac{t}{\sqrt{t^2-a^2}}dt$$

$$\therefore \int \frac{dx}{x\cdot\sqrt{x^2+a^2}}=\int \frac{1}{t\cdot\sqrt{t^2-a^2}}\cdot\frac{t}{\sqrt{t^2-a^2}}dt$$

$$=\int \frac{1}{t^2-a^2}dt$$

公式 21：$\int \frac{dx}{x^2-a^2}=\frac{1}{2a}\cdot ln\left|\frac{x-a}{x+a}\right|+C$

$$=\frac{1}{2a}\cdot ln\left|\frac{t-a}{t+a}\right|+C$$

$$=\frac{1}{2a}\cdot ln\left|\frac{(t-a)^2}{t^2-a^2}\right|+C$$

将$t=\sqrt{x^2+a^2}$代入上式得：$\int \frac{dx}{x\cdot\sqrt{x^2+a^2}}=\frac{1}{2a}\cdot ln\left|\frac{(\sqrt{x^2+a^2}-a)^2}{x^2+a^2-a^2}\right|+C$

提示：$log_a b^n=nlog_a b$

$$=\frac{1}{2a}\cdot ln\left|\frac{(\sqrt{x^2+a^2}-a)^2}{x^2}\right|+C$$

$$=\frac{1}{a}\cdot ln\frac{\sqrt{x^2+a^2}-a}{|x|}+C$$

38. $\int \frac{dx}{x^2\cdot\sqrt{x^2+a^2}}=-\frac{\sqrt{x^2+a^2}}{a^2x}+C \qquad (a>0)$

证明：$\int \frac{dx}{x^2\cdot\sqrt{x^2+a^2}}=-\int \frac{1}{\sqrt{x^2+a^2}}d\frac{1}{x}$

令$t=\frac{1}{x} \quad (t\neq 0)$，则$x=\frac{1}{t}$

$$\therefore\ -\int \frac{1}{\sqrt{x^2+a^2}}d\frac{1}{x}=-\int \frac{1}{\sqrt{\frac{1}{t^2}+a^2}}dt=-\int \frac{t}{\sqrt{1+a^2t^2}}dt$$

$$=-\frac{1}{2a^2}\int \frac{2a^2t}{\sqrt{1+a^2t^2}}dt$$

$$=-\frac{1}{2a^2}\int \frac{1}{\sqrt{1+a^2t^2}}d(1+a^2t^2)$$

$$=-\frac{1}{2a^2}\cdot\frac{1}{1-\frac{1}{2}}(1+a^2t^2)^{1-\frac{1}{2}}+C$$

$$=-\frac{1}{a^2}\cdot\sqrt{1+a^2t^2}+C$$

将$t=\frac{1}{x}$代入上式得：$\int \frac{dx}{x^2\cdot\sqrt{x^2+a^2}}=-\frac{\sqrt{x^2+a^2}}{a^2x}+C$

39. $\int \sqrt{x^2+a^2}\,dx = \frac{x}{2}\sqrt{x^2+a^2} + \frac{a^2}{2}\cdot ln\,(x+\sqrt{x^2+a^2}) + C \quad (a>0)$

证法1: $\because \int \sqrt{x^2+a^2}\,dx = x\sqrt{x^2+a^2} - \int x\,d\sqrt{x^2+a^2}$

$$= x\sqrt{x^2+a^2} - \int \frac{x^2}{\sqrt{x^2+a^2}}dx$$

$$\therefore \int \sqrt{x^2+a^2}\,dx + \int \frac{x^2}{\sqrt{x^2+a^2}}dx = x\sqrt{x^2+a^2} \qquad ①$$

又 $\int \sqrt{x^2+a^2}\,dx - \int \frac{x^2}{\sqrt{x^2+a^2}}dx = \int \frac{a^2}{\sqrt{x^2+a^2}}dx \qquad ②$

公式 31: $\int \frac{1}{\sqrt{x^2+a^2}}dx = ln(x+\sqrt{x^2+a^2}) + C \quad (a>0)$

$$= a^2\cdot ln\,(x+\sqrt{x^2+a^2}) + C_1$$

由① + ②得，$2\int \sqrt{x^2+a^2}\,dx = x\sqrt{x^2+a^2} + a^2\cdot ln\,(x+\sqrt{x^2+a^2})$

即 $\int \sqrt{x^2+a^2}\,dx = \frac{x}{2}\sqrt{x^2+a^2} + \frac{a^2}{2}\cdot ln\,(x+\sqrt{x^2+a^2}) + C$

39. $\int \sqrt{x^2+a^2}\,dx = \frac{x}{2}\cdot\sqrt{x^2+a^2} + \frac{a^2}{2}\cdot ln\,(x+\sqrt{x^2+a^2}) + C \quad (a>0)$

证法 2: 令 $x = a\cdot tant \quad (-\frac{\pi}{2} < t < \frac{\pi}{2})$，则 $\sqrt{x^2+a^2} = a\sqrt{1+tan^2 t} = |a\cdot sect|$,

$$\because -\frac{\pi}{2} < t < \frac{\pi}{2}, sec\,t = \frac{1}{cos\,t} > 0, \therefore \sqrt{x^2+a^2} = a\cdot sect$$

提示：$1+tan^2 t = sec^2 t$

$$\therefore \int \sqrt{x^2+a^2}\,dx = \int a\cdot sectd(a\cdot tant) = a^2\int sect\,dtant$$

$$= a^2 sect\cdot tant - a^2\int tantdsect \qquad ①$$

$$又 \int tantdsect = \int tant\cdot sect\cdot tantdt = \int \frac{sin^2 t}{cos^3 t}dt$$

$$= \int \frac{1-cos^2 t}{cos^3 t}dt = \int \frac{1}{cost}\cdot\frac{1}{cos^2 t}dt - \int \frac{1}{cost}dt$$

$$= \int sect\,dtant - \int sectdt \qquad ②$$

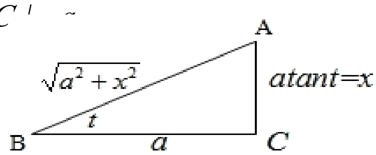
联立①②有 $a^2\int sect\,dtant = \frac{1}{2}(a^2 sect\cdot tant + a^2\int sectdt) \qquad ③$

又 $\int sectdt = ln\,|\,sect + tant\,| + C_1$ （公式 87） ④

联立③④有 $a^2\int sect\,dtant = \frac{1}{2}a^2 sect\cdot tant + \frac{1}{2}a^2 ln\,|\,sect + tant\,| + C_2 \qquad ⑤$

$\because x = a\cdot tant, \therefore$ 在RtΔABC中，可设 $\angle B = t, |\,BC$ ' ~

则 $|\,AC\,| = a\cdot tant = x, |\,AB\,| = \sqrt{a^2+x^2}$



$$\therefore sect = \frac{1}{cost} = \frac{\sqrt{a^2+x^2}}{a}, tant = \frac{x}{a}$$

$$\therefore \frac{1}{2}a^2 sect\cdot tant + \frac{1}{2}a^2 ln\,|\,sect + tant\,| = \frac{x}{2}\cdot\sqrt{x^2+a^2} + \frac{a^2}{2}\cdot ln\,|\frac{x+\sqrt{x^2+a^2}}{a}|$$

$$= \frac{x}{2}\cdot\sqrt{x^2+a^2} + \frac{a^2}{2}\cdot ln\,(x+\sqrt{x^2+a^2}) - \frac{a^2}{2}\cdot lna$$

综合①②③④⑤得 $\int \sqrt{x^2+a^2}\,dx = \frac{x}{2}\cdot\sqrt{x^2+a^2} + \frac{a^2}{2}\cdot ln\,(x+\sqrt{x^2+a^2}) + C$

40. $\int\sqrt{(x^2+a^2)^3}\,dx=\frac{x}{8}\cdot(2x^2+5a^2)\sqrt{x^2+a^2}+\frac{3}{8}\cdot a^4\cdot ln\,(x+\sqrt{x^2+a^2})+C \qquad (a>0)$

证明：被积函数 $f(x)=\sqrt{(x^2+a^2)^3}$的定义域为$\{x\,|\,x\in R\}$

可令$x=a\,tant \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$， 则$\sqrt{(x^2+a^2)^3}=|\,a^3\ sec^3t\,|$

$\because\ -\frac{\pi}{2}<t<\frac{\pi}{2},\ sect=\frac{1}{cost}>0$，$\therefore\ \sqrt{(x^2+a^2)^3}=a^3\cdot sec^3t$

$$\therefore\ \int\sqrt{(x^2+a^2)^3}\,dx=\int a^3\cdot sec^3t\,d\,(a\,tant)=a^4\int sec^3t\,d\,tant$$

$$=a^4sec^3t\cdot tant-a^4\int tant\,d\,sec^3t$$

$$=a^4sec^3t\cdot tant-a^4\int tant\cdot 3\cdot sec^2t\cdot sect\,tant\,dt$$

$$=a^4sec^3t\cdot tant-3a^4\int tan^2t\cdot sec^3t\,dt$$

$$=a^4sec^3t\cdot tant-3a^4\int tan^2t\cdot sect\,d\,tant$$

$$=a^4sec^3t\cdot tant-3a^4\int (sec^2t-1)\cdot sect\,d\,tant$$

$$=a^4sec^3t\cdot tant-3a^4\int sec^3t\,d\,tant+3a^4\int sect\,d\,tant$$

移项并整理的：$a^4\int sec^3t\,d\,tant=\frac{1}{4}(a^4sec^3t\,tant+3a^4\int sect\,d\,tant)$ ①

$$\because\ \int sect\,d\,tant=sect\cdot tant-\int tant\,d\,sect$$

$$=sect\cdot tant-\int tan^2t\cdot sectdt$$

$$=sect\cdot tant-\int (sec^2t-1)\cdot sectdt$$

$$=sect\cdot tant-\int sec^3t\,dt+\int sect\,dt$$ ②

又$\because\ \int sect\,d\,tant=\int sec^3t\,dt$ ③

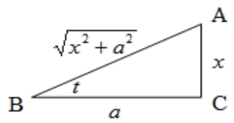
公式 87：$\int \sec t\,dt=ln\,|\,sect+tant\,|+C$

联立②③得：$a^4\int sec^3t\,d\,tant=\frac{1}{2}\cdot sect\cdot tant+\frac{1}{2}\int sect\,dt$

$$=\frac{1}{2}\cdot sect\cdot tant+\frac{1}{2}ln\,|\,sect+tant\,|+C_1$$ ④

联立①④得$a^4\int sec^3t\,d\,tant=\frac{1}{4}a^4sec^3t\cdot tant+\frac{3}{8}a^4sect\cdot tant+\frac{3}{8}a^4\cdot ln\,|\,sect+tant\,|+C_1$

在RtΔABC中，设$\angle B=t$，$|\,BC\,|=a$，则$|\,AC\,|=x$，$|\,AB\,|=\sqrt{x^2+a^2}$



$$\therefore\ tant=\frac{x}{a},\ sect=\frac{1}{\cos t}=\frac{\sqrt{x^2+a^2}}{a}$$

$$\therefore\ a^4\int sec^3t\,d\,tant=\frac{a^4}{4}\cdot\frac{x}{a}\cdot\frac{x^2+a^2}{a^3}\cdot\sqrt{x^2+a^2}+\frac{3a^4}{8}\cdot\frac{\sqrt{x^2+a^2}}{a}\cdot\frac{x}{a}+\frac{3}{8}a^4\cdot ln\left|\frac{\sqrt{x^2+a^2}+x}{a}\right|+C_1$$

$$=\frac{x}{4}(x^2+a^2)\sqrt{x^2+a^2}+\frac{3a^2\cdot x}{8}\cdot\sqrt{x^2+a^2}+\frac{3a^4}{8}\cdot ln\left|\sqrt{x^2+a^2}+x\right|+C$$

$$\therefore\ \int\sqrt{(x^2+a^2)^3}\,dx=\frac{x}{8}\cdot(2x^2+5a^2)\sqrt{x^2+a^2}+\frac{3}{8}\cdot a^4\cdot ln\,(x+\sqrt{x^2+a^2})+C$$

41. $\int x\cdot\sqrt{x^2+a^2}\,dx=\frac{1}{3}\sqrt{(x^2+a^2)^3}+C \qquad (a>0)$

证明：$\int x\cdot\sqrt{x^2+a^2}\,dx=\frac{1}{2}\int (x^2+a^2)^{\frac{1}{2}}dx^2$

$$=\frac{1}{2}\int (x^2+a^2)^{\frac{1}{2}}d(x^2+a^2)$$

$$=\frac{1}{2}\times\frac{1}{1+\frac{1}{2}}\cdot(x^2+a^2)^{1+\frac{1}{2}}+C$$

$$=\frac{1}{3}\sqrt{(x^2+a^2)^3}+C$$

42. $\int x^2 \cdot \sqrt{x^2+a^2}\,dx = \frac{x}{8}\cdot(2x^2+a^2)\sqrt{x^2+a^2} - \frac{a^4}{8}\cdot ln\,(x+\sqrt{x^2+a^2}) + C \qquad (a>0)$

证明：被积函数 $f(x) = x^2 \cdot \sqrt{x^2+a^2}$ 的定义域为 $\{x \mid x \in R\}$

可令 $x = a\,tant \quad (-\frac{\pi}{2} < t < \frac{\pi}{2})$，　则 $x^2 \cdot \sqrt{(x^2+a^2)} = a^2 tan^2 t \mid a\,sect \mid$

$\because -\frac{\pi}{2} < t < \frac{\pi}{2},\ sect = \frac{1}{cost} > 0$，$\therefore\ x^2 \cdot \sqrt{(x^2+a^2)} = a^3 tan^2 t \cdot sect$

$$\therefore \int x^2 \cdot \sqrt{(x^2+a^2)}\,dx = \int a^3 tan^2 t \cdot sect\, d\,(a\,tant) = a^4 \int tan^2 t \cdot sect\, d\,tant = a^4 \int tan^2 t \cdot sec^3 t\, dt$$

$$= a^4 \int tant \cdot sec^2 t\, dsect$$

$$= a^4 \int tant \cdot (1+tan^2 t)\, dsect = a^4 \int tant\, dsect + a^4 \int tan^3 t\, dsect$$

$$= a^4 \int tant\, dsect + a^4 \cdot tan^3 t \cdot sect - a^4 \int sect\, dtan^3 t$$

$$= a^4 \int tant\, dsect + a^4 \cdot tan^3 t \cdot sect - 3a^4 \int sec^3 t\, tan^2 t\, dt$$

$$= a^4 \int tant\, dsect + a^4 \cdot tan^3 t \cdot sect - 3a^4 \int sec^2 t\, tant\, dsect$$

移项并整理的：$a^4 \int tant \cdot sec^2 t\, dsect = \frac{1}{4}(a^4 \int tant\, dsect + a^4 \cdot tan^3 t \cdot sect)$

$$= \frac{a^4}{4} \int tant\, dsect + \frac{a^4}{4} \cdot tan^3 t \cdot sect \qquad ①$$

$$\because \int tant\, d\,sect = sect \cdot tant - \int sect\, dtant \ = sect \cdot tant - \int sec^3 t dt$$

$$= sect \cdot tant - \int (1+tan^2 t) \cdot sectdt$$

$$= sect \cdot tant - \int sect\, dt - \int tan^2 t\, sect\, dt$$

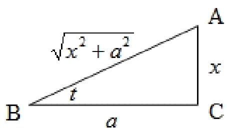
$$= sect \cdot tant - \int sect\, dt - \int tant\, d\,sect$$

移项并整理得：$\int tant\, d\,sect = \frac{1}{2} \cdot sect \cdot tant - \frac{1}{2}\int sect\, dt$　　公式87：$\int \sec t\, dt = ln \mid sect + tant \mid + C$

$$= \frac{1}{2} \cdot sect \cdot tant - \frac{1}{2} ln \mid sect + tant \mid + C_1 \qquad ②$$

联立①②得：$a^4 \int tant \cdot sec^2 t\, dsect = \frac{a^4}{8} sect \cdot tant - \frac{a^4}{8} ln \mid sect + tant \mid + \frac{a^4}{4} tan^3 t \cdot sect + C_1$

在RtΔABC中，设$\angle B = t$，$\mid BC \mid = a$，则$\mid AC \mid = x$，$\mid AB \mid = \sqrt{x^2+a^2}$



$\therefore\ tant = \frac{x}{a},\ sect = \frac{1}{\cos t} = \frac{\sqrt{x^2+a^2}}{a}$

$$\therefore\ a^4 \int tant \cdot sec^2 t\, dsect = \frac{a^4}{8} \cdot \frac{x}{a} \cdot \frac{\sqrt{x^2+a^2}}{a} - \frac{a^4}{8} \cdot ln \left| \frac{\sqrt{x^2+a^2}+x}{a} \right| + \frac{a^4}{4} \cdot \frac{x^3}{a^3} \cdot \frac{\sqrt{x^2+a^2}}{a} + C_1$$

$$= \frac{a^4 x}{8} \cdot \sqrt{x^2+a^2} - \frac{a^4}{8} \cdot ln \left| \sqrt{x^2+a^2} + x \right| + \frac{x^3}{4} \cdot \sqrt{x^2+a^2} + C_2$$

$$= \frac{x}{8} \cdot (2x^2+a^2)\sqrt{x^2+a^2} - \frac{a^4}{8} \cdot ln \left| \sqrt{x^2+a^2} + x \right| + C$$

$\because \sqrt{x^2+a^2} + x > 0$，$\therefore\ \frac{a^4}{8} \cdot ln \left| \sqrt{x^2+a^2} + x \right| = \frac{a^4}{8} \cdot ln\,(x + \sqrt{x^2+a^2})$

$$\therefore \int x^2 \cdot \sqrt{x^2+a^2}\,dx = \frac{x}{8} \cdot (2x^2+a^2)\sqrt{x^2+a^2} - \frac{a^4}{8} \cdot ln\,(x+\sqrt{x^2+a^2}) + C$$

43． $\int \frac{\sqrt{x^2+a^2}}{x}dx=\sqrt{x^2+a^2}+a\cdot ln\frac{\sqrt{x^2+a^2}-a}{|x|}+C \qquad (a>0)$

证明：被积函数 $f(x)=\frac{\sqrt{x^2+a^2}}{x}$ 的定义域为 $\{x\,|\,x\neq 0\}$

令 $\sqrt{x^2+a^2}=t \quad (t\geq 0 且 t\neq a)$，则 $x=\sqrt{t^2-a^2}$

$$\therefore\ dx=\frac{1}{2}(t^2-a^2)^{-\frac{1}{2}}\cdot 2tdt=\frac{t}{\sqrt{t^2-a^2}}dt$$

$$\therefore\ \int\frac{\sqrt{x^2+a^2}}{x}dx=\int\frac{t}{\sqrt{t^2-a^2}}\cdot\frac{t}{\sqrt{t^2-a^2}}dt=\int\frac{t^2}{t^2-a^2}dt$$

$$=\int\frac{t^2-a^2+a^2}{t^2-a^2}dt=\int dt+a^2\int\frac{1}{t^2-a^2}dt$$

公式 21：$\int\frac{dx}{x^2-a^2}=\frac{1}{2a}\cdot ln\left|\frac{x-a}{x+a}\right|+C$

$$=t+a^2\cdot\frac{1}{2a}\cdot ln\left|\frac{t-a}{t+a}\right|+C=t+\frac{a}{2}\cdot ln\left|\frac{(t-a)^2}{t^2-a^2}\right|+C$$

将 $t=\sqrt{x^2+a^2}$ 代入上式得：$\int\frac{\sqrt{x^2+a^2}}{x}dx=\sqrt{x^2+a^2}+\frac{a}{2}\cdot ln\left|\frac{(\sqrt{x^2+a^2}-a)^2}{x^2+a^2-a^2}\right|+C$

$$=\sqrt{x^2+a^2}+a\cdot ln\left|\frac{(\sqrt{x^2+a^2}-a)}{x}\right|+C$$

$$=\sqrt{x^2+a^2}+a\cdot ln\frac{\sqrt{x^2+a^2}-a}{|x|}+C$$

44． $\int\frac{\sqrt{x^2+a^2}}{x^2}dx=-\frac{\sqrt{x^2+a^2}}{x}+ln\,(x+\sqrt{x^2+a^2})+\mathrm{C} \qquad (a>0)$

证明：被积函数 $f(x)=\frac{\sqrt{x^2+a^2}}{x^2}$ 的定义域为 $\{x\,|\,x\neq 0\}$

1. 当 $x>0$ 时，可令 $x=a\,tant \quad (0<t<\frac{\pi}{2})$， 则 $dx=d(a\,tant)=a\,sec^2tdt$，

$$\frac{\sqrt{x^2+a^2}}{x^2}=\frac{|\,a\,sect\,|}{a^2\,tan^2t}\ ,\ \because\ 0<t<\frac{\pi}{2},\ sect=\frac{1}{cost}>0\ ,\ \therefore\ \frac{\sqrt{x^2+a^2}}{x^2}=\frac{sect}{a\,tan^2t}$$

$$\therefore\ \int\frac{\sqrt{x^2+a^2}}{x^2}dx=\int\frac{sect}{a\,tan^2t}\cdot a\,sec^2tdt=\int\frac{sect}{tan^2t}\cdot(1+tan^2t)dt$$

$$=\int sect\,dt+\int\frac{sect}{tan^2t}\cdot dt=\int sect\,dt+\int\frac{1}{cost}\cdot\frac{cos^2t}{sin^2t}dt$$

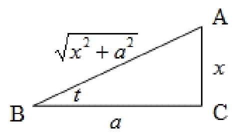
$$=\int sect\,dt+\int\frac{cost}{sin^2t}dt=\int sect\,dt+\int\frac{1}{sin^2t}dsint$$

公式 87：$\int\sec t\,dt=ln|\,sect+tant\,|+C$

$$=ln\,|\,sect+tant\,|-\frac{1}{sint}+C_1$$

在 Rt$\varDelta ABC$ 中，设 $\angle\mathrm{B}=t$，$|\,BC\,|=a$，则 $|\,\mathrm{AC}\,|=x$，$|\,\mathrm{AB}\,|=\sqrt{x^2+a^2}$

$$\therefore\ sint=\frac{x}{\sqrt{x^2+a^2}},\ tant=\frac{x}{a},\ sect=\frac{1}{cost}=\frac{\sqrt{x^2+a^2}}{a}$$



$$\therefore\ \int\frac{\sqrt{x^2+a^2}}{x^2}dx=ln\left|\frac{\sqrt{x^2+a^2}+x}{a}\right|-\frac{\sqrt{x^2+a^2}}{x}+C_1$$

$$=-\frac{\sqrt{x^2+a^2}}{x}+ln\left|\sqrt{x^2+a^2}+x\right|-lna+C_1$$

$$\because\ \sqrt{x^2+a^2}+x>0 \qquad \therefore\ \int\frac{\sqrt{x^2+a^2}}{x^2}dx=-\frac{\sqrt{x^2+a^2}}{x}+ln\,(\sqrt{x^2+a^2}+x)+\mathrm{C}$$

2. 当 $x<0$ 时，同理可证得：$\int\frac{\sqrt{x^2+a^2}}{x^2}dx=-\frac{\sqrt{x^2+a^2}}{x}+ln\,(\sqrt{x^2+a^2}+x)+\mathrm{C}$

综合讨论 1，2 得：$\int\frac{\sqrt{x^2+a^2}}{x^2}dx=-\frac{\sqrt{x^2+a^2}}{x}+ln\,(\sqrt{x^2+a^2}+x)+\mathrm{C}$

（七）含有 $\sqrt{x^2-a^2}$ $(a>0)$ 的积分（45~58）

45. $\int\frac{dx}{\sqrt{x^2-a^2}}=\frac{x}{|x|}\cdot arsh\frac{|x|}{a}+C_1=ln|x+\sqrt{x^2-a^2}|+C \qquad (a>0)$

证法1:被积函数 $f(x)=\frac{1}{\sqrt{x^2-a^2}}$ 的定义域为 $\{x\,|\,x>a或x<-a\}$

1. 当 $x>a$ 时，可设 $x=a\cdot sect\quad(0<t<\frac{\pi}{2})$，则 $dx=a\cdot sect\cdot tantdt$

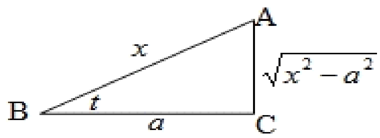
$\sqrt{x^2-a^2}=a\sqrt{sec^2t-1}=a\cdot|tant|\ \because 0<t<\frac{\pi}{2}$，$\sqrt{x^2-a^2}=a\cdot tant$

$\therefore\int\frac{dx}{\sqrt{x^2-a^2}}=\int\frac{a\cdot sect\cdot tant}{a\cdot tant}dt=\int sectdt$ 　公式 87: $\int sectdt=ln|sect+tant|+C$

$=ln|sect+tant|+C_2$

在Rt ΔABC中，可设 $\angle B=t,|BC|=a$，则 $|AB|=x,|AC|=\sqrt{x^2-a^2}$

$\therefore\ sec\,t=\frac{1}{cos\,t}=\frac{x}{a},\ tan\,t=\frac{|AC|}{|BC|}=\frac{\sqrt{x^2-a^2}}{a}$



$\therefore\int\frac{dx}{\sqrt{x^2-a^2}}=ln|sec\,t+tan\,t|=ln|\frac{x+\sqrt{x^2-a^2}}{a}|$

$=ln|x+\sqrt{x^2-a^2}|+C_3$

2 .当 $x<-a$，即 $-x>a$ 时，令 $\mu=-x$，即 $x=-\mu$

由讨论 1可知 $\int\frac{dx}{\sqrt{x^2-a^2}}=-\int\frac{d\mu}{\sqrt{\mu^2-a^2}}=-ln|\mu+\sqrt{\mu^2-a^2}|+C_4$

$=-ln|-x+\sqrt{x^2-a^2}|+C_4=ln\frac{1}{|-x+\sqrt{x^2-a^2}|}+C_4$

$=ln\frac{|-x+\sqrt{x^2-a^2}|}{a^2}+C_4$

$=ln|-x-\sqrt{x^2-a^2}|+C_5$

综合讨论 1,2，可写成 $\int\frac{dx}{\sqrt{x^2-a^2}}=\frac{x}{|x|}\cdot arsh\frac{|x|}{a}+C_1=ln|x+\sqrt{x^2-a^2}|+C$

45. $\int\frac{dx}{\sqrt{x^2-a^2}}=\frac{x}{|x|}\cdot arsh\frac{|x|}{a}+C_1=ln|x+\sqrt{x^2-a^2}|+C \qquad (a>0)$

证法2: 被积函数 $f(x)=\frac{1}{\sqrt{x^2-a^2}}$ 的定义域为 $\{x\,|\,x>a\text{或}x<-a\}$

1. 当 $x>a$ 时，可设 $x=a\cdot cht\ (t>0)$, 则 $t=arch\frac{x}{a}$

$$\sqrt{x^2-a^2}=\sqrt{a^2ch^2t-a^2}=a\cdot sht\ ,\ dx=a\cdot shtdt$$

$$\therefore\int\frac{dx}{\sqrt{x^2-a^2}}=\int\frac{a\cdot sht}{a\cdot sht}dt=\int dt=t+C_1$$

$$=arch\frac{x}{a}+C=ln\left[\frac{x}{a}+\sqrt{\left(\frac{x}{a}\right)^2-1}\right]+C_2$$

$$=ln|x+\sqrt{x^2-a^2}|+C_3$$

2. 当 $x<-a$, 即 $-x>a$ 时，令 $\mu=-x$, 即 $x=-\mu$

由讨论1可知 $\int\frac{dx}{\sqrt{x^2-a^2}}=-\int\frac{d\mu}{\sqrt{\mu^2-a^2}}=-ln|\mu+\sqrt{\mu^2-a^2}|+C_4$

$$=-ln(-x+\sqrt{x^2-a^2})+C_4=ln\frac{1}{|-x+\sqrt{x^2-a^2}|}+C_4$$

$$=ln\frac{|-x+\sqrt{x^2-a^2}|}{a^2}+C_4$$

$$=ln|-x-\sqrt{x^2-a^2}|+C_5$$

综合讨论1,2，可写成 $\int\frac{dx}{\sqrt{x^2-a^2}}=\frac{x}{|x|}\cdot arsh\frac{|x|}{a}+C_1=ln|x+\sqrt{x^2-a^2}|+C$

46. $\int \frac{dx}{\sqrt{(x^2-a^2)^3}} = -\frac{x}{a^2 \cdot \sqrt{x^2-a^2}} + C \qquad (a>0)$

证明:被积函数 $f(x) = \frac{1}{\sqrt{(x^2-a^2)^3}}$ 的定义域为$\{x \mid x>a 或 x<-a\}$

1. 当$x>a$时,可设$x = a\cdot sect \quad (0<t<\frac{\pi}{2})$,则$dx = a\cdot sect\cdot tantdt$

$\sqrt{(x^2-a^2)^3} = \left|a^3\cdot tan^3 t\right| \qquad \because 0<t<\frac{\pi}{2}$,$tant>0$,$\sqrt{(x^2-a^2)^3} = a^3\cdot tan^3 t$

$$\therefore \int \frac{dx}{\sqrt{(x^2-a^2)^3}} = \int \frac{a\cdot sect\cdot tant}{a^3\cdot tan^3 t}dt = \frac{1}{a^2}\int \frac{sect}{tan^3 t}dt$$

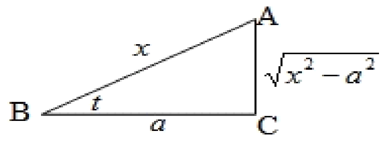
$$= \frac{1}{a^2}\int \frac{1}{cos\,t}\cdot\frac{cos^2 t}{sin^2 t}dt = \frac{1}{a^2}\int \frac{cos\,t}{sin^2 t}dt$$

$$= \frac{1}{a^2}\int \frac{1}{sin^2 t}d\,sint$$

$$= -\frac{1}{a^2\,sin\,t} + C$$

在Rt ΔABC中,可设 $\angle B = t, |BC| = a$,则$|AB| = x, |AC| = \sqrt{x^2-a^2}$

$$\therefore sin\,t = \frac{\sqrt{x^2-a^2}}{x}$$



$$\therefore \int \frac{dx}{\sqrt{(x^2-a^2)^3}} = -\frac{x}{a^2\cdot\sqrt{x^2-a^2}} + C$$

2. 当$x<-a$,即$-x>a$时,令 $\mu = -x$,即$x = -\mu$

$$\therefore \int \frac{dx}{\sqrt{(x^2-a^2)^3}} = -\int \frac{d\mu}{\sqrt{(\mu^2-a^2)^3}}$$

由讨论 1可知 $-\int \frac{d\mu}{\sqrt{(\mu^2-a^2)^3}} = \frac{\mu}{a^2\cdot\sqrt{(\mu^2-a^2)}} + C$

将$\mu = -x$代入得:$\int \frac{dx}{\sqrt{(x^2-a^2)^3}} = -\frac{x}{a^2\cdot\sqrt{x^2-a^2}} + C$

综合讨论 1,2 得: $\int \frac{dx}{\sqrt{(x^2-a^2)^3}} = -\frac{x}{a^2\cdot\sqrt{x^2-a^2}} + C$

47. $\int \frac{x}{\sqrt{x^2-a^2}}dx = \sqrt{x^2-a^2} + C \qquad (a>0)$

证明:$\int \frac{x}{\sqrt{x^2-a^2}}dx = \frac{1}{2}\int (x^2-a^2)^{-\frac{1}{2}}dx^2$

$$= \frac{1}{2}\int (x^2-a^2)^{-\frac{1}{2}}d(x^2-a^2)$$

$$= \frac{1}{2}\times\frac{1}{1-\frac{1}{2}}(x^2-a^2)^{1-\frac{1}{2}} + C$$

$$= \sqrt{x^2-a^2} + C$$

48. $\int \frac{x}{\sqrt{(x^2-a^2)^3}}dx = -\frac{1}{\sqrt{x^2-a^2}}+C \qquad (a>0)$

证明:被积函数 $f(x)=\frac{x}{\sqrt{(x^2-a^2)^3}}$ 的定义域为$\{x \mid x>a或x<-a\}$

1. 当$x>a$时,可设$x=a\cdot sect \quad (0<t<\frac{\pi}{2})$, 则$dx=a\cdot sect\cdot tantdt$

$$\frac{x}{\sqrt{(x^2-a^2)^3}}=\frac{a\cdot sect}{|a^3\cdot tan^3 t|} \quad \because 0<t<\frac{\pi}{2}\ ,\ \frac{x}{\sqrt{(x^2-a^2)^3}}=\frac{sect}{a^2\cdot tan^3 t}$$

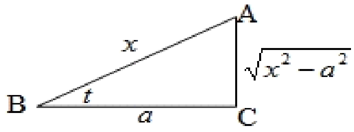
$$\therefore \int \frac{x}{\sqrt{(x^2-a^2)^3}}dx=\int \frac{sect}{a^2\cdot tan^3 t}\cdot a\cdot sect\cdot tant\,dt$$

$$=\frac{1}{a}\int \frac{sec^2 t}{tan^2 t}dt=\frac{1}{a}\int \frac{1}{sin^2 t}dt$$

$$=-\frac{1}{a}\int -csc^2 tdt=-\frac{1}{a}\cdot cot\,t+C$$

在Rt ΔABC中, 可设 $\angle B=t, |BC|=a$, 则$|AB|=x, |AC|=\sqrt{x^2-a^2}$

$$\therefore\ cot\,t=\frac{a}{\sqrt{x^2-a^2}}$$



$$\therefore \int \frac{x}{\sqrt{(x^2-a^2)^3}}dx=-\frac{1}{a}\cdot\frac{a}{\sqrt{x^2-a^2}}+C=-\frac{1}{\sqrt{x^2-a^2}}+C$$

2 .当$x<-a$,即$-x>a$时, 令 $\mu=-x$,即$x=-\mu$

$$\therefore\ \int \frac{x}{\sqrt{(x^2-a^2)^3}}dx=\int \frac{\mu}{\sqrt{(\mu^2-a^2)^3}}d\mu$$

由讨论 1可知 $\int \frac{\mu}{\sqrt{(\mu^2-a^2)^3}}d\mu=-\frac{1}{\sqrt{\mu^2-a^2}}+C$

将$\mu=-x$代入得:$\int \frac{x}{\sqrt{(x^2-a^2)^3}}dx=-\frac{1}{\sqrt{x^2-a^2}}+C$

综合讨论 1,2 得:$\int \frac{x}{\sqrt{(x^2-a^2)^3}}dx=-\frac{1}{\sqrt{x^2-a^2}}+C$

49. $\int \frac{x^2}{\sqrt{x^2-a^2}}dx=\frac{x}{2}\sqrt{x^2-a^2}+\frac{a^2}{2}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C \qquad (a>0)$

证明:$\int \frac{x^2}{\sqrt{x^2-a^2}}dx=\int \frac{x^2-a^2+a^2}{\sqrt{x^2-a^2}}dx$

$$=\int (\sqrt{x^2-a^2}+\frac{a^2}{\sqrt{x^2-a^2}})dx$$

$$=\int \sqrt{x^2-a^2}\,dx+a^2\int \frac{1}{\sqrt{x^2-a^2}}dx$$

$\because \int \sqrt{x^2-a^2}\,dx=\frac{x}{2}\cdot\sqrt{x^2-a^2}-\frac{a^2}{2}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$ ① (公式53)

$a^2\int \frac{dx}{\sqrt{x^2-a^2}}=a^2\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$ ② (公式45)

$\therefore$ 由①+②得:$\int \frac{x^2}{\sqrt{x^2-a^2}}dx=\frac{x}{2}\sqrt{x^2-a^2}+\frac{a^2}{2}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$

50. $\int \frac{x^2}{\sqrt{(x^2-a^2)^3}}dx = -\frac{x}{\sqrt{x^2-a^2}} + ln\left| x+\sqrt{x^2-a^2} \right| + C \qquad (a>0)$

证明:被积函数 $f(x)=\frac{x^2}{\sqrt{(x^2-a^2)^3}}$ 的定义域为 $\{x \mid x>a或x<-a\}$

1. 当 $x>a$时,可设 $x=a\cdot sect \quad (0<t<\frac{\pi}{2})$,则 $dx=a\cdot sect\cdot tantdt$

$$\frac{x^2}{\sqrt{(x^2-a^2)^3}}=\frac{a^2\cdot sec^2t}{\left|a^3\cdot tan^3 t\right|} \because 0<t<\frac{\pi}{2},\therefore \frac{x^2}{\sqrt{(x^2-a^2)^3}}=\frac{sec^2 t}{a\cdot tan^3 t}$$

$$\therefore \int \frac{x^2}{\sqrt{(x^2-a^2)^3}}dx=\int \frac{sec^2 t}{a\cdot tan^3 t}\cdot a\cdot sect\cdot tant\,dt=\int \frac{sec^3 t}{tan^2 t}dt=\int \frac{1}{cos^3 t}\cdot\frac{cos^2 t}{sin^2 t}dt=\int \frac{1}{sin^2 t\cdot cos\, t}dt$$

$$=\int \frac{cos\, t}{sin^2 t\cdot cos^2 t}dt=\int \frac{1}{sin^2 t(1-sin^2 t)}d\,sin\,t=\int(\frac{1}{sin^2 t}+\frac{1}{1-sin^2 t})d\,sin\,t$$

$$=\int \frac{1}{sin^2 t}d\,sin\,t+\int \frac{1}{1-sin^2 t}d\,sin\,t=\int \frac{1}{sin^2 t}d\,sin\,t-\int \frac{1}{sin^2 t-1}d\,sin\,t$$

$$=\int \frac{1}{sin^2 t}d\,sin\,t+\frac{1}{2}\int(\frac{1}{sin\,t+1}-\frac{1}{sin\,t-1})d\,sin\,t$$

$$=\int \frac{1}{sin^2 t}d\,sin\,t+\frac{1}{2}\int \frac{1}{sin\,t+1}d(sin\,t+1)-\frac{1}{2}\int \frac{1}{sin\,t-1}d(sin\,t-1)$$

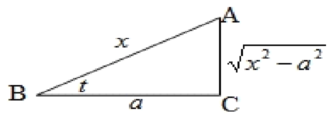
$$=-\frac{1}{sin\,t}+\frac{1}{2}ln\left| sin\,t+1\right|-\frac{1}{2}ln\left| sin\,t-1\right|+C_1$$

$$=-\frac{1}{sin\,t}+\frac{1}{2}ln\left|\frac{sin\,t+1}{sin\,t-1}\right|+C_1=-\frac{1}{sin\,t}+\frac{1}{2}ln\left|\frac{(sin\,t+1)^2}{sin^2 t-1}\right|+C_1$$

$$=-\frac{1}{sin\,t}+\frac{1}{2}ln\left|\frac{(sin\,t+1)^2}{cos^2 t}\cdot(-1)\right|+C_1=-\frac{1}{sin\,t}+ln\left| tan\,t+sec\,t\right|+C_2$$

在Rt ΔABC中, 可设 $\angle B=t, |BC|=a$,则 $|AB|=x, |AC|=\sqrt{x^2-a^2}$

$$\therefore \quad sin\,t=\frac{\sqrt{x^2-a^2}}{x},\ tan\,t=\frac{\sqrt{x^2-a^2}}{a},\ sec\,t=\frac{x}{a}$$



$$\therefore \int \frac{x^2}{\sqrt{(x^2-a^2)^3}}dx=-\frac{x}{\sqrt{x^2-a^2}}+ln\left|\frac{x+\sqrt{x^2-a^2}}{a}\right|+C_2=-\frac{x}{\sqrt{x^2-a^2}}+ln\left| x+\sqrt{x^2-a^2}\right|+C$$

2. 当 $x<-a$,即 $-x>a$时, 令 $\mu=-x$,即 $x=-\mu$

$$\therefore \int \frac{x^2}{\sqrt{(x^2-a^2)^3}}dx=-\int \frac{\mu^2}{\sqrt{(\mu^2-a^2)^3}}d\mu$$

由讨论 1可知 $-\int \frac{\mu^2}{\sqrt{(\mu^2-a^2)^3}}d\mu=\frac{\mu}{\sqrt{\mu^2-a^2}}-ln\left|\mu+\sqrt{\mu^2-a^2}\right|+C$

将 $\mu=-x$代入得: $\int \frac{x^2}{\sqrt{(x^2-a^2)^3}}dx=-\frac{x}{\sqrt{x^2-a^2}}-ln\left|-x+\sqrt{x^2-a^2}\right|+C$

$$=\int \frac{x^2}{\sqrt{(x^2-a^2)^3}}dx=-\frac{x}{\sqrt{x^2-a^2}}-ln\left|\frac{(\sqrt{x^2-a^2}-x)(\sqrt{x^2-a^2}+x)}{\sqrt{x^2-a^2}+x}\right|+C$$

$$=-\frac{x}{\sqrt{x^2-a^2}}-ln\left|\frac{x^2-a^2-x^2}{(\sqrt{x^2-a^2}+x)}\right|+C=-\frac{x}{\sqrt{x^2-a^2}}+2\,ln\,a-ln\left|\frac{1}{\sqrt{x^2-a^2}+x}\right|+C$$

提示: $log_a b^n = n log_a b$

$$=-\frac{x}{\sqrt{x^2-a^2}}+ln\left| x+\sqrt{x^2-a^2}\right|+C$$

综合讨论 1,2 得: $\int \frac{x^2}{\sqrt{(x^2-a^2)^3}}dx=-\frac{x}{\sqrt{x^2-a^2}}+ln\left| x+\sqrt{x^2-a^2}\right|+C$

51. $\int \frac{dx}{x\sqrt{x^2-a^2}}=\frac{1}{a}\cdot arccos\frac{a}{|x|}+C \qquad (a>0)$

证法1:被积函数$f(x)=\frac{1}{x\sqrt{x^2-a^2}}$的定义域为$\{x\,|\,x>a或x<-a\}$

1. 当$x>a$时,可设$x=a\cdot sect \quad (0<t<\frac{\pi}{2})$, 则

$x\sqrt{x^2-a^2}=a^2\cdot sect\sqrt{sec^2t-1}=a^2 sect\cdot tant$,$dx=a\cdot sect\cdot tant\,dt$

$$\therefore \int \frac{dx}{x\sqrt{x^2-a^2}}=\int \frac{a\cdot sect\cdot tant}{a^2 sect\cdot tant}dt=\int \frac{1}{a}dt$$

$$=\frac{1}{a}t+C_1$$

$\because x=a\cdot sect, \therefore cost=\frac{a}{x}, \therefore \ t=arccos\frac{a}{x}$

$$\therefore \int \frac{dx}{x\sqrt{x^2-a^2}}=\frac{1}{a}\cdot arccos\frac{a}{x}+C$$

2 .当$x<-a$,即$-x>a$时，令 $\mu=-x$,即$x=-\mu$

由讨论1可知$\int \frac{dx}{x\sqrt{x^2-a^2}}=\int \frac{d\mu}{\mu\sqrt{\mu^2-a^2}}=\frac{1}{a}\cdot arccos\frac{a}{\mu}+C_2$

$$=\frac{1}{a}\cdot arccos\frac{a}{-x}+C$$

综合讨论1,2，可写成$\int \frac{dx}{x\sqrt{x^2-a^2}}=\frac{1}{a}\cdot arccos\frac{a}{|x|}+C$

51. $\int \frac{dx}{x\sqrt{x^2-a^2}} = \frac{1}{a} \cdot arccos\frac{a}{|x|} + C \qquad (a>0)$

证法2：被积函数 $f(x)=\frac{1}{x\sqrt{x^2-a^2}}$ 的定义域为 $\{x \mid x>a 或 x<-a\}$

1. 当 $x>a$ 时，可设 $x=a\cdot cht \quad (0<t)$，则

$x\sqrt{x^2-a^2}=a\cdot cht\cdot a\cdot sht=a^2 cht\cdot sht$，$dx=a\cdot sht\,dt$

$$\therefore \int \frac{dx}{x\sqrt{x^2-a^2}} = \int \frac{a\cdot sht}{a\cdot cht\cdot sht}dt = \int \frac{1}{a}\cdot\frac{1}{cht}dt$$

$$= \frac{1}{a}\int \frac{cht}{ch^2 t}dt = \frac{1}{a}\int \frac{1}{1+sh^2 t}dsht$$

$$= \frac{1}{a}\cdot arctan(sht)+C$$

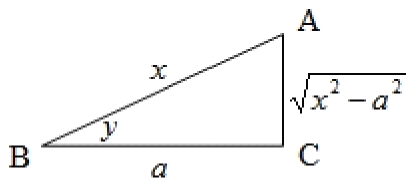
公式19：$\int \frac{dx}{x^2+a^2} = \frac{1}{a} arctan\frac{x}{a}+C$

$\because x=a\cdot cht$，$\therefore cht=\frac{x}{a}$，$\therefore sht=\sqrt{1-ch^2 t}=\frac{\sqrt{x^2-a^2}}{a}$

在RtΔABC中，设 $tany=sht=\frac{\sqrt{x^2-a^2}}{a}$，$\angle B=y$，$|BC|=a$

$\therefore y=arctan(sht)$，$|AC|=\sqrt{x^2-a^2}$，$|AB|=\sqrt{|AC|^2+|BC|^2}=x$

$\therefore cosy=\frac{|BC|}{|AB|}=\frac{a}{x}$



即 $cosy=cos\,arctan(sht)=\frac{a}{x}$

$\therefore arctan(sht)=arccos\frac{a}{x}+C$

$$\therefore \int \frac{dx}{x\sqrt{x^2-a^2}} = \frac{1}{a}\cdot arctan(sht)+C = \frac{1}{a}\cdot arccos\frac{a}{x}+C$$

2. 当 $x<-a$，即 $-x>a$ 时，令 $\mu=-x$，即 $x=-\mu$

由讨论1可知 $\int \frac{dx}{x\sqrt{x^2-a^2}} = \int \frac{d\mu}{\mu\sqrt{\mu^2-a^2}} = \frac{1}{a}\cdot arccos\frac{a}{\mu}+C_2$

$$= \frac{1}{a}\cdot arccos\frac{a}{-x}+C$$

综合讨论1,2，可写成 $\int \frac{dx}{x\sqrt{x^2-a^2}} = \frac{1}{a}\cdot arccos\frac{a}{|x|}+C$

52. $\int \frac{dx}{x^2\sqrt{x^2-a^2}} = \frac{\sqrt{x^2-a^2}}{a^2 x} + C \qquad (a>0)$

证明：被积函数 $f(x) = \frac{1}{x^2\sqrt{x^2-a^2}}$ 的定义域为 $\{x \mid x>a 或 x<-a\}$

1. 当 $x>a$ 时，可设 $x = \frac{1}{t} \quad (0<t<\frac{1}{a})$，则 $dx = -\frac{1}{t^2}dt$，$\frac{1}{x^2\sqrt{x^2-a^2}} = \frac{t^3}{\sqrt{1-a^2t^2}}$

$$\therefore \int \frac{dx}{x^2\sqrt{x^2-a^2}} = \int \frac{t^3}{\sqrt{1-a^2t^2}}\cdot(-\frac{1}{t^2})dt$$

$$= -\int \frac{t}{\sqrt{1-a^2t^2}}dt = -\frac{1}{2}\int (1-a^2t^2)^{-\frac{1}{2}}dt^2$$

$$= \frac{1}{2a^2}\int (1-a^2t^2)^{-\frac{1}{2}}d(1-a^2t^2) = \frac{1}{2a^2}\cdot\frac{1}{1-\frac{1}{2}}\cdot(1-a^2t^2)^{1-\frac{1}{2}} + C$$

$$= \frac{\sqrt{1-a^2t^2}}{a^2} + C$$

将 $x=\frac{1}{t}$，即 $t=\frac{1}{x}$ 代入上式得：$\int \frac{dx}{x^2\sqrt{x^2-a^2}} = \frac{1}{a^2}\cdot\sqrt{1-a^2(\frac{1}{x})^2} + C = \frac{1}{a^2}\cdot\sqrt{\frac{x^2-a^2}{x^2}} + C$

$$= \frac{1}{a^2}\cdot\frac{\sqrt{x^2-a^2}}{|x|} + C$$

$\because x>a>0 \quad \therefore \int \frac{dx}{x^2\sqrt{x^2-a^2}} = \frac{\sqrt{x^2-a^2}}{a^2 x} + C$

2. 当 $x<-a$，即 $-x>a$ 时，令 $\mu=-x$，即 $x=-\mu$

由讨论 1 可知 $\int \frac{dx}{x^2\sqrt{x^2-a^2}} = -\int \frac{d\mu}{\mu^2\sqrt{\mu^2-a^2}} = -\frac{\sqrt{\mu^2-a^2}}{a^2\mu} + C$

将 $\mu=-x$ 代入上式得：$\int \frac{dx}{x^2\sqrt{x^2-a^2}} = \frac{\sqrt{x^2-a^2}}{a^2 x} + C$

综合讨论 1，2 得：$\int \frac{dx}{x^2\sqrt{x^2-a^2}} = \frac{\sqrt{x^2-a^2}}{a^2 x} + C$

53. $\int\sqrt{x^2-a^2}\,dx=\frac{x}{2}\sqrt{x^2-a^2}-\frac{a^2}{2}\cdot ln\left|\,x+\sqrt{x^2-a^2}\,\right|+C \qquad (a>0)$

证明:被积函数 $f(x)=\sqrt{x^2-a^2}$的定义域为 $\{x\,|\,x>a或x<-a\}$

1. 当$x>a$时,可设 $x=a\cdot sect \quad (0<t<\frac{\pi}{2})$,则$\sqrt{x^2-a^2}=\left|\,a\cdot tan\,t\,\right|$

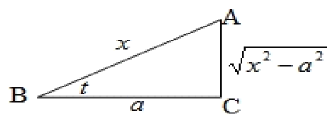
$\because 0<t<\frac{\pi}{2}$,$\therefore\ \sqrt{x^2-a^2}=a\cdot tan\,t$

$$\begin{aligned}\therefore\ \int\sqrt{x^2-a^2}\,dx&=\int a\cdot tan\,t\,d\,(a\cdot sect)=a^2\int tan\,t\,d\,sec\,t\\&=a^2\cdot tan\,t\cdot sec\,t-a^2\int sec\,t\,d\,tan\,t\\&=a^2\cdot tan\,t\cdot sec\,t-a^2\int sec^3\,t\,dt\\&=a^2\cdot tan\,t\cdot sec\,t-a^2\int sec\,t\,(1+tan^2\,t)\,dt\\&=a^2\cdot tan\,t\cdot sec\,t-a^2\int sec\,t\,dt-a^2\int sec\,t\,tan^2\,t\,dt\\&=a^2\cdot tan\,t\cdot sec\,t-a^2\int sec\,t\,dt-a^2\int tan\,t\,d\,sec\,t\\&=a^2\cdot tan\,t\cdot sec\,t-a^2\cdot ln\left|\,sec\,t+tan\,t\,\right|-a^2\int tan\,t\,d\,sec\,t\end{aligned}$$

移项并整理得:$a^2\int tan\,t\,d\,sec\,t=\frac{a^2}{2}\cdot tan\,t\cdot sec\,t-\frac{a^2}{2}\cdot ln\left|\,sec\,t+tan\,t\,\right|+C_1$

在Rt ΔABC中,可设 $\angle B=t\,,|\,BC\,|=a\,$,则$|\,AB\,|=x\,,|\,AC\,|=\sqrt{x^2-a^2}$

$\therefore\ \ tan\,t=\frac{\sqrt{x^2-a^2}}{a}$, $sec\,t=\frac{x}{a}$



$$\begin{aligned}\therefore\ \int\sqrt{x^2-a^2}\,dx&=a^2\int tan\,t\,d\,sec\,t\\&=\frac{a^2}{2}\cdot\frac{\sqrt{x^2-a^2}}{a}\cdot\frac{x}{a}-\frac{a^2}{2}\cdot ln\left|\frac{\sqrt{x^2-a^2}+x}{a}\right|+C_1\\&=\frac{x}{2}\sqrt{x^2-a^2}-\frac{a^2}{2}\cdot ln\left|\,x+\sqrt{x^2-a^2}\,\right|+C\end{aligned}$$

2 .当$x<-a$时,可设 $x=a\cdot sect \quad (-\frac{\pi}{2}<t<0)$ 同理可证

综合讨论 1,2得:$\int\sqrt{x^2-a^2}\,dx==\frac{x}{2}\sqrt{x^2-a^2}-\frac{a^2}{2}\cdot ln\left|\,x+\sqrt{x^2-a^2}\,\right|+C$

54. $\int\sqrt{(x^2-a^2)^3}\,dx=\frac{x}{8}\cdot(2x^2-5a^2)\sqrt{x^2-a^2}+\frac{3}{8}\cdot a^4\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C\qquad(a>0)$

证明：$\int\sqrt{(x^2-a^2)^3}\,dx=x\cdot(x^2-a^2)^{\frac{3}{2}}-\int xd(x^2-a^2)^{\frac{3}{2}}$

$$=x\cdot(x^2-a^2)^{\frac{3}{2}}-\int x\cdot\frac{3}{2}\cdot(2x)\cdot(x^2-a^2)^{\frac{1}{2}}dx$$

$$=x\cdot(x^2-a^2)^{\frac{3}{2}}-3\int x^2(x^2-a^2)^{\frac{1}{2}}dx$$

$$=x\cdot(x^2-a^2)^{\frac{3}{2}}-3\int(x^2-a^2+a^2)(x^2-a^2)^{\frac{1}{2}}dx$$

$$=x\cdot(x^2-a^2)^{\frac{3}{2}}-3\int(x^2-a^2)^{\frac{3}{2}}dx-3a^2\int(x^2-a^2)^{\frac{1}{2}}dx$$

移项并整理得：$\int\sqrt{(x^2-a^2)^3}\,dx=\frac{x}{4}\cdot(x^2-a^2)^{\frac{3}{2}}-\frac{3a^2}{4}\int(x^2-a^2)^{\frac{1}{2}}dx$ ①

又$\int(x^2-a^2)^{\frac{1}{2}}dx=\frac{x}{2}\sqrt{x^2-a^2}-\frac{a^2}{2}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$ （公式53） ②

联立①②得：

$$\int\sqrt{(x^2-a^2)^3}\,dx=\frac{x}{4}(x^2-a^2)^{\frac{3}{2}}-\frac{3x}{8}\cdot a^2\cdot\sqrt{x^2-a^2}+\frac{3}{8}\cdot a^4\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$$

$$=(\frac{x^3}{4}-\frac{a^2x}{4})\sqrt{x^2-a^2}-\frac{3x}{8}\cdot a^2\cdot\sqrt{x^2-a^2}+\frac{3}{8}\cdot a^4\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$$

$$=\frac{x}{8}\cdot(2x^2-5a^2)\sqrt{x^2-a^2}+\frac{3}{8}\cdot a^4\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$$

55. $\int x\sqrt{x^2-a^2}\,dx=\frac{1}{3}\sqrt{(x^2-a^2)^3}+\mathrm{C}\qquad(a>0)$

证明：$\int x\sqrt{x^2-a^2}\,dx=\frac{1}{2}\int\sqrt{x^2-a^2}\,dx^2$

$$=\frac{1}{2}\int(x^2-a^2)^{\frac{1}{2}}d(x^2-a^2)$$

$$=\frac{1}{2}\times\frac{1}{1+\frac{1}{2}}\cdot(x^2-a^2)^{1+\frac{1}{2}}+C$$

$$=\frac{1}{3}\sqrt{(x^2-a^2)^3}+\mathrm{C}$$

56. $\int x^2\sqrt{x^2-a^2}\,dx=\frac{x}{8}\cdot(2x^2-a^2)\sqrt{x^2-a^2}-\frac{a^4}{8}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C \qquad (a>0)$

证明：被积函数 $f(x)=x^2\sqrt{x^2-a^2}$的定义域为$\{x\,|\,x>a或x<-a\}$

1.当$x>a$时，可令$x=a\cdot sect \quad (0<t<\frac{\pi}{2})$，则$x^2\sqrt{x^2-a^2}=a^2sec^2t\,|\,a\,tant\,|$

$\because\ 0<t<\frac{\pi}{2}, tan\,t>0$，$\therefore\ x^2\sqrt{x^2-a^2}=a^3sec^2t\cdot tant$

$$\therefore\ \int x^2\sqrt{x^2-a^2}\,dx=\int a^3sec^2t\cdot tant\ d\,(a\ sect)=a^4\int sec^3t\ d\ tan^2t\ dt \qquad ①$$

$$=\frac{a^4}{3}\int sect\cdot 3\cdot sec^2t\cdot tan^2\ t\ dt=\frac{a^4}{3}\int sect\ d\ tan^3\ t$$

$$=\frac{a^4}{3}\cdot sec\ t\cdot tan^3\ t-\frac{a^4}{3}\int tan^3\ t\ d\ sec\ t$$

$$=\frac{a^4}{3}\cdot sec\ t\cdot tan^3\ t-\frac{a^4}{3}\int tan\ t\,(sec^2\ t-1)\,d\ sec\ t$$

$$=\frac{a^4}{3}\cdot sec\ t\cdot tan^3\ t-\frac{a^4}{3}\int tan\ t\cdot sec^2\ td\ sec\ t+\frac{a^4}{3}\int tan\ t\ d\ sec\ t$$

$$=\frac{a^4}{3}\cdot sec\ t\cdot tan^3\ t-\frac{a^4}{3}\int tan^2\ t\cdot sec^3\ t\ dt+\frac{a^4}{3}\int tan\ t\ d\ sec\ t$$

移项并整理得：$a^4\int sec^3t\ d\ tan^2t\ dt=\frac{a^4}{4}\cdot sec\ t\cdot tan^3\ t+\frac{a^4}{4}\int tan\ t\ d\ sec\ t \qquad ②$

又 $\int tant\ d\ sect=sect\cdot tant-\int sect\ dtant\ =sect\cdot tant-\int sec^3tdt$

$$=sect\cdot tant-\int(1+tan^2t)\cdot sectdt$$

$$=sect\cdot tant-\int sect\ dt-\int tan^2t\ sect\ dt$$

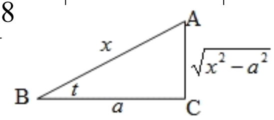
$$=sect\cdot tant-\int sect\ dt-\int tant\ d\ sect$$

移项并整理得：$\int tant\ d\ sect=\frac{1}{2}\cdot sect\cdot tant-\frac{1}{2}\int sect\ dt$

$$=\frac{1}{2}\cdot sect\cdot tant-\frac{1}{2}ln\,|\,sect+tant\,|+C_1 \qquad ③$$

将③式代入②式得：$a^4\int sec^3t\ d\ tan^2t\ dt=\frac{a^4}{4}tan^3t\cdot sect+\frac{a^4}{8}sect\cdot tant-\frac{a^4}{8}ln\,|\,sect+tant\,|+C_1$

在RtΔABC中，设$\angle B=t$，$|BC|=a$，则$|AB|=x$，$|AC|=\sqrt{x^2-a^2}$



$\therefore\ tant=\frac{\sqrt{x^2-a^2}}{a}, sect=\frac{1}{cos\,t}=\frac{x}{a}$

$$\therefore\ a^4\int sec^3t\ d\ tan^2t\ dt=\frac{a^4}{4}\cdot\frac{x}{a}\cdot\frac{x^2-a^2}{a^3}\cdot\sqrt{x^2-a^2}+\frac{a^4}{8}\cdot\frac{\sqrt{x^2-a^2}}{a}\cdot\frac{x}{a}-\frac{a^4}{8}\cdot ln\left|\frac{x+\sqrt{x^2-a^2}}{a}\right|+C_1$$

$$=\frac{x}{4}\cdot(x^2-a^2)\cdot\sqrt{x^2-a^2}+\frac{a^2x}{8}\cdot\sqrt{x^2-a^2}-\frac{a^4}{8}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C_2$$

$$=\frac{x}{8}\cdot(2x^2-a^2)\sqrt{x^2-a^2}-\frac{a^4}{8}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$$

2. 当$x<-a$,即$-x>a$时，令$\mu=-x$,则$x=-\mu$

由讨论1得：$\int x^2\sqrt{x^2-a^2}\,dx=-\int\mu^2\sqrt{\mu^2-a^2}\,d\mu$

$$=\frac{-\mu}{8}\cdot(2\mu^2-a^2)\sqrt{\mu^2-a^2}+\frac{a^4}{8}\cdot ln\left|-\mu+\sqrt{\mu^2-a^2}\right|+C$$

将$\mu=-x$代入上式得：$\int x^2\sqrt{x^2-a^2}\,dx=\frac{x}{8}\cdot(2x^2-a^2)\sqrt{x^2-a^2}-\frac{a^4}{8}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$

综合讨论 1,2得：$\int x^2\sqrt{x^2-a^2}\,dx=\frac{x}{8}\cdot(2x^2-a^2)\sqrt{x^2-a^2}-\frac{a^4}{8}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$

57. $\int \frac{\sqrt{x^2-a^2}}{x}dx=\sqrt{x^2-a^2}-a\cdot arccos\ \frac{a}{|x|}+C \qquad (a>0)$

证法1:被积函数 $f(x)=\frac{\sqrt{x^2-a^2}}{x}$的定义域为 $\{x\,/\,x>a或x<-a\}$

1. 当$x>a$时，可设 $x=a\cdot sect \quad (0<t<\frac{\pi}{2})$,

则$\frac{\sqrt{x^2-a^2}}{x}=\frac{a\cdot tant}{a\cdot sect}$ ， $dx=a\cdot sect\cdot tant\ d\ t$

$\therefore \int \frac{\sqrt{x^2-a^2}}{x}dx=\int \frac{a\cdot tant\cdot a\cdot sect\cdot tant}{a\cdot sect}dt=\int a\cdot tan^2tdt$

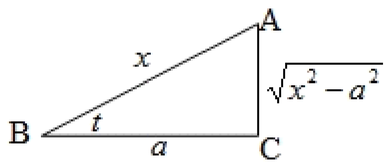
$=a\int \frac{sin^2t}{cos^2t}dt=a\int \frac{1-cos^2t}{cos^2t}dt=a\int \frac{1}{cos^2t}dt-\int dt$

$=a\cdot tant-a\cdot t+C$

$\because\ x=a\cdot sect,\ \therefore\ cost=\frac{a}{x},\ \therefore\ t=arccos\ \frac{a}{x}$

在$Rt\Delta ABC$中，设$\angle B=t, |BC|=a$，则$|AB|=x, |AC|=\sqrt{x^2-a^2}$

$\therefore\ tant=\frac{|AC|}{|BC|}=\frac{\sqrt{x^2-a^2}}{a}$



$\therefore \int \frac{\sqrt{x^2-a^2}}{x}dx=a\cdot tant-a\cdot t+C$

$=\sqrt{x^2-a^2}-a\cdot arccos\ \frac{a}{x}+C$

2 .当$x<-a$,即$-x>a$时，令 $\mu=-x$,即$x=-\mu$

由讨论 1可知$\int \frac{\sqrt{x^2-a^2}}{x}dx=\int \frac{\sqrt{\mu^2-a^2}}{\mu}d\mu=\sqrt{\mu^2-a^2}-a\cdot arccos\ \frac{a}{\mu}+C$

$=\sqrt{x^2-a^2}-a\cdot arccos\ \frac{a}{-x}+C$

综合讨论 1,2，可写成：$\int \frac{\sqrt{x^2-a^2}}{x}dx=\sqrt{x^2-a^2}-a\cdot arccos\ \frac{a}{|x|}+C$

57. $\int \frac{\sqrt{x^2-a^2}}{x}dx = \sqrt{x^2-a^2} - a\cdot arccos\frac{a}{|x|} + C \qquad (a>0)$

证法 2：被积函数 $f(x)=\frac{\sqrt{x^2-a^2}}{x}$ 的定义域为 $\{x\,|\,x>a 或 x<-a\}$

1. 当 $x>a$ 时，可设 $x=a\cdot ch\,t \quad (0<t)$，

则 $\frac{\sqrt{x^2-a^2}}{x}=\frac{a\cdot sht}{a\cdot cht}=\frac{sht}{cht}$，$dx=a\cdot sht\,dt$

$\therefore \int\frac{\sqrt{x^2-a^2}}{x}dx=\int\frac{sht}{cht}\cdot a\cdot sht\,dt = a\int\frac{sh^2t}{cht}dt$

$= a\int\frac{ch^2t-1}{cht}dt = a\int chtdt - a\int\frac{cht}{ch^2t}dt$

$= a\int chtdt - a\int\frac{1}{1+sh^2t}dsht$

$= a\cdot sht - a\cdot arctan(sht)+C$

提示：$ch^2t-sh^2t=1$
$(cht)'=sht$
$(sh\,t)'=cht$

公式19：$\int\frac{dx}{x^2+a^2}=\frac{1}{a}\cdot arctan\frac{x}{a}+C$

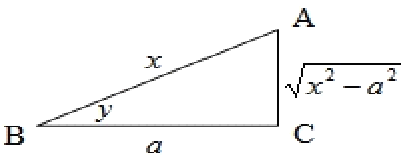
$\because\ x=a\cdot cht,\ \therefore\ cht=\frac{x}{a},\ \therefore\ sht=\sqrt{1-ch^2t}=\frac{\sqrt{x^2-a^2}}{a}$

在RtΔABC中，设 $tany=sht=\frac{\sqrt{x^2-a^2}}{a}$，$\angle B=y$，$|BC|=a$

$\therefore\ y=arctan(sht)$，$|AC|=\sqrt{x^2-a^2}$，$|AB|=\sqrt{|AC|^2+|BC|^2}=x$

$\therefore\ cosy=\frac{|BC|}{|AB|}=\frac{a}{x}$

即 $cosy=cos\,arctan(sht)=\frac{a}{x}$



$\therefore\ arctan(sht)=arccos\frac{a}{x}$

$\therefore\ \int\frac{\sqrt{x^2-a^2}}{x}dx=\sqrt{x^2-a^2}-a\cdot arccos\frac{a}{x}+C$

2. 当 $x<-a$，即 $-x>a$ 时，令 $\mu=-x$，即 $x=-\mu$

由讨论 1可知 $\int\frac{\sqrt{x^2-a^2}}{x}dx=\int\frac{\sqrt{\mu^2-a^2}}{\mu}d\mu=\sqrt{\mu^2-a^2}-a\cdot arccos\frac{a}{\mu}+C$

$=\sqrt{x^2-a^2}-a\cdot arccos\frac{a}{-x}+C$

综合讨论 1，2，可写成：$\int\frac{\sqrt{x^2-a^2}}{x}dx=\sqrt{x^2-a^2}-a\cdot arccos\frac{a}{|x|}+C$

58. $\int \frac{\sqrt{x^2-a^2}}{x^2}dx = -\frac{\sqrt{x^2-a^2}}{x} + ln\left| x+\sqrt{x^2-a^2} \right| + C \qquad (a>0)$

证明：$\int \frac{\sqrt{x^2-a^2}}{x^2}dx = -\int \sqrt{x^2-a^2}\,d\frac{1}{x}$

$$= -\frac{\sqrt{x^2-a^2}}{x} + \int \frac{1}{x}d\sqrt{x^2-a^2}$$

$$= -\frac{\sqrt{x^2-a^2}}{x} + \int \frac{1}{x}\cdot\frac{1}{2}\cdot 2x\cdot(x^2-a^2)^{-\frac{1}{2}}dx$$

$$= -\frac{\sqrt{x^2-a^2}}{x} + \int \frac{1}{\sqrt{x^2-a^2}}dx$$

公式45：$\int \frac{dx}{\sqrt{x^2-a^2}} = ln\left| x+\sqrt{x^2-a^2} \right| + C$

$$= -\frac{\sqrt{x^2-a^2}}{x} + ln\left| x+\sqrt{x^2-a^2} \right| + C$$

（八）含有 $\sqrt{a^2-x^2}$ $(a>0)$ 的积分（59~72）

59. $\int \frac{dx}{\sqrt{a^2-x^2}} = arcsin\frac{x}{a} + C \qquad (a>0)$

证明：被积函数 $f(x)=\frac{1}{\sqrt{a^2-x^2}}$ 的定义域为 $\{x|-a<x<a\}$

$\therefore$ 可设 $x=a\cdot sint \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$，则 $dx=a\cdot cost\,dt$，$\frac{1}{\sqrt{a^2-x^2}}=\frac{1}{|a\cdot cost|}$

$\because -\frac{\pi}{2}<t<\frac{\pi}{2}$，$cost>0$ $\therefore$ $\frac{1}{\sqrt{a^2-x^2}}=\frac{1}{a\cdot cost}$

$$\therefore \int \frac{dx}{\sqrt{a^2-x^2}} = \int \frac{1}{a\cdot cost}\cdot a\cdot cost\,dt$$

$$= \int dt$$

$$= t + C$$

$\because x=a\cdot sint \quad \therefore t=arcsin\frac{x}{a}$

$$\therefore \int \frac{dx}{\sqrt{a^2-x^2}} = arcsin\frac{x}{a} + C$$

60. $\int\frac{dx}{\sqrt{(a^2-x^2)^3}}=\frac{x}{a^2\cdot\sqrt{a^2-x^2}}+C \qquad (a>0)$

证明:被积函数 $f(x)=\frac{1}{\sqrt{(a^2-x^2)^3}}$ 的定义域为 $\{x|-a<x<a\}$

$\therefore$ 可设 $x=a\cdot sint \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$，则 $dx=a\cdot cost\,dt$，$\frac{1}{\sqrt{(a^2-x^2)^3}}=\frac{1}{|a^3\cdot cos^3 t|}$

$\because -\frac{\pi}{2}<t<\frac{\pi}{2}$，$cost>0$ $\therefore$ $\frac{1}{\sqrt{(a^2-x^2)^3}}=\frac{1}{a^3\cdot cos^3 t}$

$$\therefore \int\frac{dx}{\sqrt{(a^2-x^2)^3}}=\int\frac{1}{a^3\cdot cos^3 t}\cdot a\cdot cost\,dt$$

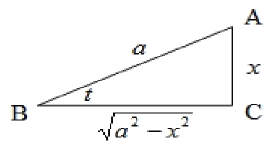
$$=\int\frac{1}{a^2\cdot cos^2 t}dt$$

$$=\int\frac{1}{a^2}\cdot sec^2 t\,dt$$

$$=\frac{1}{a^2}\cdot tant+C$$

在Rt ΔABC中，设 $\angle B=t,|AB|=a$，则 $|AC|=x,|BC|=\sqrt{a^2-x^2}$

$$\therefore\ tant=\frac{x}{\sqrt{a^2-x^2}}$$



$$\therefore\ \int\frac{dx}{\sqrt{(a^2-x^2)^3}}=\frac{x}{a^2\cdot\sqrt{a^2-x^2}}+C$$

61. $\int\frac{x}{\sqrt{a^2-x^2}}dx=-\sqrt{a^2-x^2}+\mathrm{C} \qquad (a>0)$

证明:$\int\frac{x}{\sqrt{a^2-x^2}}dx=\frac{1}{2}\int(a^2-x^2)^{-\frac{1}{2}}dx^2$

$$=-\frac{1}{2}\int(a^2-x^2)^{-\frac{1}{2}}d(a^2-x^2)$$

$$=-\frac{1}{2}\times\frac{1}{1-\frac{1}{2}}\cdot(a^2-x)^{1-\frac{1}{2}}+C$$

$$=-\sqrt{a^2-x^2}+\mathrm{C}$$

62. $\int \frac{x}{\sqrt{(a^2-x^2)^3}}\,dx = \frac{1}{\sqrt{a^2-x^2}} + C \qquad (a>0)$

证明：$\int \frac{x}{\sqrt{(a^2-x^2)^3}}\,dx = \frac{1}{2}\int (a^2-x^2)^{-\frac{3}{2}}\,dx^2$

$$= -\frac{1}{2}\int (a^2-x^2)^{-\frac{3}{2}}\,d(a^2-x^2)$$

$$= -\frac{1}{2}\times\frac{1}{1-\frac{3}{2}}\cdot(a^2-x^2)^{1-\frac{3}{2}} + C$$

$$= \frac{1}{\sqrt{a^2-x^2}} + C$$

63. $\int \frac{x^2}{\sqrt{a^2-x^2}}\,dx = -\frac{x}{2}\sqrt{a^2-x^2} + \frac{a^2}{2}\cdot arcsin\,\frac{x}{a} + C \qquad (a>0)$

证明：被积函数 $f(x)=\frac{x^2}{\sqrt{a^2-x^2}}$ 的定义域为 $\{x\,|\,-a<x<a\}$

$\therefore$ 可设 $x = a\cdot sint \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$，则 $dx = a\cdot\cos t\,dt$ ，$\frac{x^2}{\sqrt{a^2-x^2}} = \frac{a^2\cdot sin^2 t}{|\,a\cdot cost\,|}$

$\because\ -\frac{\pi}{2}<t<\frac{\pi}{2}$ ，$\cos t>0$ $\therefore$ $\frac{x^2}{\sqrt{a^2-x^2}} = \frac{a\cdot sin^2 t}{cost}$

$\therefore\ \int \frac{x^2}{\sqrt{a^2-x^2}}\,dx = \int \frac{a\cdot sin^2 t}{cost}\cdot a\cdot\cos t\,dt$

$$= a^2\int sin^2 t\,dt$$

$$= a^2\int \frac{1-\cos 2t}{2}\,dt$$

$$= \frac{a^2}{2}\int dt - \frac{a^2}{4}\int \cos 2t\,d(2t)$$

$$= \frac{a^2}{2}\cdot t - \frac{a^2}{4}\cdot sin2t + C$$

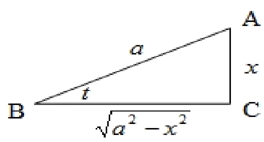
$$= \frac{a^2}{2}\cdot t - \frac{a^2}{2}\cdot sint\cdot cost + C$$

> 提示：$cos2t = cos^2 t - sin^2 t$
> $= 1 - 2sin^2 t$
> $sin2t = 2\cdot sint\cdot cost$

在Rt ΔABC中，设 $\angle B = t$，$|AB| = a$，则 $|AC| = x$，$|BC| = \sqrt{a^2-x^2}$

$\therefore\ sint = \frac{x}{a}$ ，$cost = \frac{\sqrt{a^2-x^2}}{a}$

$\therefore\ \int \frac{x^2}{\sqrt{a^2-x^2}}\,dx = -\frac{x}{2}\sqrt{a^2-x^2} + \frac{a^2}{2}\cdot arcsin\,\frac{x}{a} + C$



64. $\int \frac{x^2}{\sqrt{(a^2-x^2)^3}}\,dx = \frac{x}{\sqrt{a^2-x^2}} - arcsin\,\frac{x}{a} + C \qquad (a > 0)$

证明：被积函数 $f(x) = \frac{x^2}{\sqrt{(a^2-x^2)^3}}$ 的定义域为 $\{x \mid -a < x < a\}$

$\therefore$ 可设 $x = a \cdot sint \quad (-\frac{\pi}{2} < t < \frac{\pi}{2})$，则 $dx = a \cdot \cos t\,dt$，$\frac{x^2}{\sqrt{(a^2-x^2)^3}} = \frac{a^2 \cdot sin^2 t}{\left| a^3 \cdot cos^3 t \right|}$

$\because -\frac{\pi}{2} < t < \frac{\pi}{2}$，$\cos t > 0$ $\therefore$ $\frac{x^2}{\sqrt{(a^2-x^2)^3}} = \frac{sin^2 t}{a \cdot cos^3 t}$

$$\therefore \int \frac{x^2}{\sqrt{a^2-x^2}}\,dx = \int \frac{sin^2 t}{a \cdot cos^3 t} \cdot a \cdot \cos t\,dt$$

$$= \int \frac{sin^2 t}{cos^2 t}\,dt$$

$$= \int \frac{1 - cos^2 t}{cos^2 t}\,dt$$

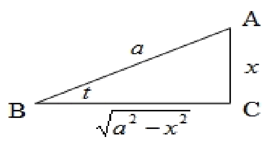
$$= \int \frac{1}{cos^2 t}\,dt - \int dt$$

$$= \int d\,tant - \int dt$$

$$= tant - t + C$$

在Rt ΔABC中，设 $\angle B = t$，$|AB| = a$，则 $|AC| = x$，$|BC| = \sqrt{a^2 - x^2}$

$$\therefore \quad tant = \frac{x}{\sqrt{a^2-x^2}}$$



$$\therefore \int \frac{x^2}{\sqrt{(a^2-x^2)^3}}\,dx = \frac{x}{\sqrt{a^2-x^2}} - arcsin\,\frac{x}{a} + C$$

65. $\int \frac{dx}{x\sqrt{a^2-x^2}} = \frac{1}{a}\cdot ln\frac{a-\sqrt{a^2-x^2}}{|x|}+C \qquad (a>0)$

证明：被积函数 $f(x)=\frac{1}{x\sqrt{a^2-x^2}}$ 的定义域为 $\{x\,|-a<x<a且x\neq 0\}$

1.当 $-a<x<0$ 时，可设 $x=a\cdot sint \quad (-\frac{\pi}{2}<t<0)$，则 $dx=a\cdot cos\,t\,dt$

$x\sqrt{a^2-x^2}=a\cdot sint\cdot|a\cdot cos\,t|\quad \because -\frac{\pi}{2}<t<0,\ cos\,t>0\quad \therefore\ x\sqrt{a^2-x^2}=a^2\cdot sint\cdot cos\,t$

$$\therefore \int\frac{dx}{x\sqrt{a^2-x^2}}=\int\frac{1}{a^2\cdot sint\cdot cos\,t}\cdot a\cdot cos\,t\,dt$$

$$=\frac{1}{a}\int\frac{1}{sint}dt$$

$$=\frac{1}{a}\int\frac{sint}{sin^2t}dt$$

$$=-\frac{1}{a}\int\frac{1}{1-cos^2t}d\,cos\,t$$

$$=-\frac{1}{2a}\int(\frac{1}{1+cost}+\frac{1}{1-cost})d\,cos\,t$$

$$=-\frac{1}{2a}\int\frac{1}{1+cost}d(cos\,t+1)+\frac{1}{2a}\int\frac{1}{1-cost}d(1-cos\,t)$$

$$=-\frac{1}{2a}\cdot ln|1+cost|+\frac{1}{2a}\cdot ln|cost-1|+C_1$$

$$=\frac{1}{2a}\cdot ln\left|\frac{cost-1}{1+cost}\right|+C_1$$

$$=\frac{1}{2a}\cdot ln\left|\frac{(cost-1)^2}{1-cos^2t}\cdot(-1)\right|+C_1$$

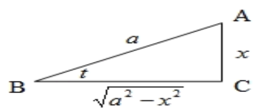
$$=\frac{1}{2a}\cdot ln\left|\frac{(cost-1)^2}{sin^2t}\right|+C_2$$

$$=\frac{1}{a}\cdot ln\left|\frac{cost-1}{sint}\right|+C_2$$

$$=\frac{1}{a}\cdot ln|cott-csct|+C_2$$

在Rt ΔABC中，设 $\angle B=t,|AB|=a$，则 $|AC|=x,|BC|=\sqrt{a^2-x^2}$

$\therefore\ cott=\frac{\sqrt{a^2-x^2}}{x}$，$csct=\frac{1}{sint}=\frac{a}{x}$



$$\therefore \int\frac{dx}{x\sqrt{a^2-x^2}}=\frac{1}{a}\cdot ln\left|\frac{\sqrt{a^2-x^2}-a}{x}\right|+C_2=\frac{1}{a}\cdot ln\left|\frac{a-\sqrt{a^2-x^2}}{x}\cdot(-1)\right|+C_2$$

$$=\frac{1}{a}\cdot ln\left|\frac{a-\sqrt{a^2-x^2}}{x}\right|+C_3$$

$\because\ a-\sqrt{a^2-x^2}>0$

$$\therefore \int\frac{dx}{x\sqrt{a^2-x^2}}=\frac{1}{a}\cdot ln\frac{a-\sqrt{a^2-x^2}}{|x|}+C$$

2.当 $0<x<a$ 时，可设 $x=a\cdot sint \quad (0<t<\frac{\pi}{2})$，同理可证

综合讨论 1,2 得：$\int\frac{dx}{x\sqrt{a^2-x^2}}=\frac{1}{a}\cdot ln\frac{a-\sqrt{a^2-x^2}}{|x|}+C$

66. $\int \frac{dx}{x^2\sqrt{a^2-x^2}} = -\frac{\sqrt{a^2-x^2}}{a^2 x} + C \qquad (a>0)$

证明：被积函数 $f(x)=\frac{1}{x^2\sqrt{a^2-x^2}}$ 的定义域为 $\{x \mid -a<x<a \text{且} x\neq 0\}$

1.当 $-a<x<0$ 时，可设 $x=a\cdot sint \quad (-\frac{\pi}{2}<t<0)$，则 $dx=a\cdot\cos t\,dt$，

$$\frac{1}{x^2\sqrt{a^2-x^2}} = \frac{1}{a^2\cdot sin^2 t}\cdot\frac{1}{|a\cdot\cos t|}$$

$\because -\frac{\pi}{2}<t<\frac{\pi}{2}$，$\cos t>0$ $\therefore \frac{1}{x^2\sqrt{a^2-x^2}} = \frac{1}{a^3\cdot sin^2 t\cdot cost}$

$$\therefore \int\frac{dx}{x^2\sqrt{a^2-x^2}} = \int\frac{1}{a^3\cdot sin^2 t\cdot cost}\cdot a\cdot\cos t\,dt$$

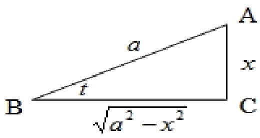
$$= \frac{1}{a^2}\int\frac{1}{sin^2 t}dt$$

$$= -\frac{1}{a^2}\int -csc^2 t\,dt$$

$$= -\frac{1}{a^2}\cdot cott + C$$

在Rt ΔABC 中，设 $\angle B=t$，$|AB|=a$，则 $|AC|=x$，$|BC|=\sqrt{a^2-x^2}$

$$\therefore \ cott = \frac{\sqrt{a^2-x^2}}{x}$$



$$\therefore \int\frac{dx}{x^2\sqrt{a^2-x^2}} = -\frac{\sqrt{a^2-x^2}}{a^2 x} + C$$

2.当 $0<x<a$ 时，可设 $x=a\cdot sint \quad (0<t<\frac{\pi}{2})$，同理可证

综合讨论 1，2 得：$\int\frac{dx}{x^2\sqrt{a^2-x^2}} = -\frac{\sqrt{a^2-x^2}}{a^2 x} + C$

67. $\int \sqrt{a^2 - x^2}\, dx = \frac{x}{2}\sqrt{a^2 - x^2} + \frac{a^2}{2} \cdot arcsin\, \frac{x}{a} + C \qquad (a > 0)$

证明:被积函数 $f(x) = \sqrt{a^2 - x^2}$ 的定义域为 $\{x \mid -a < x < a\}$

$\therefore$ 可设 $x = a \cdot sint \quad (-\frac{\pi}{2} < t < \frac{\pi}{2})$, 则 $dx = a \cdot cos\, t\, dt$,$\sqrt{a^2 - x^2} = |\, a \cdot cos\, t\,|$

$\because -\frac{\pi}{2} < t < \frac{\pi}{2}$, $cos\, t > 0$ $\therefore$ $\sqrt{a^2 - x^2} = a \cdot cos\, t$

$$\begin{aligned} \therefore \int \sqrt{a^2 - x^2}\, dx &= \int a \cdot cos\, t \cdot a \cdot cos\, t\, dt \\ &= a^2 \int cos^2 t\, dt \\ &= a^2 \int (1 - sin^2 t)\, dt \\ &= a^2 \int dt - a^2 \int sin^2 t\, dt \qquad ① \end{aligned}$$

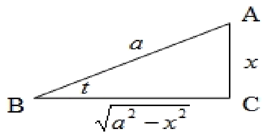
$$\begin{aligned} \text{又} \int \sqrt{a^2 - x^2}\, dx &= a^2 \int cos^2 t\, dt \\ &= a^2 \int cost\, d\, sint \\ &= a^2 \cdot sint \cdot cost - a^2 \int sint\, d\, cost \\ &= a^2 \cdot sint \cdot cost + a^2 \int sin^2 t\, dt \qquad ② \end{aligned}$$

由① + ②得: $2\int \sqrt{a^2 - x^2}\, dx = a^2 \int dt + a^2 \cdot sint \cdot cost = a^2 t + a^2 \cdot sint \cdot cost$

$$\therefore \int \sqrt{a^2 - x^2}\, dx = \frac{a^2}{2} t + \frac{a^2}{2} \cdot sint \cdot cost + C$$

在Rt ΔABC中, 设 $\angle B = t, |AB| = a$, 则 $|AC| = x, |BC| = \sqrt{a^2 - x^2}$

$\therefore \quad sint = \frac{x}{a}$, $cost = \frac{\sqrt{a^2 - x^2}}{a}$



$$\begin{aligned} \therefore \int \sqrt{a^2 - x^2}\, dx &= \frac{a^2}{2} \cdot arcsin\, \frac{x}{a} + \frac{a^2}{2} \cdot \frac{\sqrt{a^2 - x^2}}{a} \cdot \frac{x}{a} + C \\ &= \frac{x}{2}\sqrt{a^2 - x^2} + \frac{a^2}{2} \cdot arcsin\, \frac{x}{a} + C \end{aligned}$$

68. $\int\sqrt{(a^2-x^2)^3}\,dx=\frac{x}{8}\cdot(5a^2-2x^2)\sqrt{a^2-x^2}+\frac{3}{8}\cdot a^4\cdot arcsin\frac{x}{a}+C \qquad (a>0)$

证明：$\int\sqrt{(a^2-x^2)^3}\,dx=x\cdot(a^2-x^2)^{\frac{3}{2}}-\int xd\,(a^2-x^2)^{\frac{3}{2}}$

$$=x\cdot(a^2-x^2)^{\frac{3}{2}}-\int x\cdot\frac{3}{2}\cdot(-2x)\cdot(a^2-x^2)^{\frac{1}{2}}d\,x$$

$$=x\cdot(a^2-x^2)^{\frac{3}{2}}+3\int x^2(a^2-x^2)^{\frac{1}{2}}d\,x$$

$$=x\cdot(a^2-x^2)^{\frac{3}{2}}+3\int(x^2-a^2+a^2)(a^2-x^2)^{\frac{1}{2}}d\,x$$

$$=x\cdot(a^2-x^2)^{\frac{3}{2}}-3\int(a^2-x^2)^{\frac{3}{2}}d\,x+3a^2\int(a^2-x^2)^{\frac{1}{2}}d\,x$$

移项并整理得：$\int\sqrt{(a^2-x^2)^3}\,dx=\frac{x}{4}\cdot(a^2-x^2)^{\frac{3}{2}}+\frac{3a^2}{4}\int(a^2-x^2)^{\frac{1}{2}}d\,x$ ①

又$\int(a^2-x^2)^{\frac{1}{2}}d\,x=\frac{x}{2}\sqrt{a^2-x^2}+\frac{a^2}{2}\cdot arcsin\frac{x}{a}+C$ (公式 67) ②

联立①②得：

$$\int\sqrt{(a^2-x^2)^3}\,dx=\frac{x}{4}(a^2-x^2)^{\frac{3}{2}}+\frac{3x}{8}\cdot a^2\cdot\sqrt{a^2-x^2}+\frac{3}{8}\cdot a^4\cdot arcsin\frac{x}{a}+C$$

$$=(\frac{a^2x}{4}-\frac{x^3}{4})\sqrt{a^2-x^2}+\frac{3x}{8}\cdot a^2\cdot\sqrt{a^2-x^2}+\frac{3}{8}\cdot a^4\cdot arcsin\frac{x}{a}+C$$

$$=\frac{x}{8}\cdot(5a^2-2x^2)\sqrt{a^2-x^2}+\frac{3}{8}\cdot a^4\cdot arcsin\frac{x}{a}+C$$

69. $\int x\sqrt{a^2-x^2}dx=-\frac{1}{3}\sqrt{(a^2-x^2)^3}+C \qquad (a>0)$

证明：被积函数 $f(x)=x\sqrt{a^2-x^2}$ 的定义域为 $\{x\,|\,-a<x<a\}$

$\therefore$ 可设$x=a\cdot sint \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$，则 $dx=a\cdot\cos t\,dt$ ，$x\sqrt{a^2-x^2}=a\cdot\sin t\cdot|\,a\cdot\cos t\,|$

$\because -\frac{\pi}{2}<t<\frac{\pi}{2}$ ，$\cos t>0$ $\therefore$ $x\sqrt{a^2-x^2}=a^2\cdot sint\cdot cost$

$\therefore$ $\int x\sqrt{a^2-x^2}dx=\int a^2\cdot sint\cdot cost\cdot a\cdot\cos t\,dt=a^3\int\cos^2 t\cdot sint\,dt$

$$=-a^3\int cos^2 t\,dcost=-\frac{a^3}{3}cos^3 t+C$$

$$=-\frac{a^3}{3}(1-sin^2 t)^{\frac{3}{2}}+C$$

$\because$ $x=a\cdot sint \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$ ，$\therefore$ $sint=\frac{x}{a}$

$\therefore$ $(1-sin^2 t)^{\frac{3}{2}}=(\frac{a^2-x^2}{a^2})^{\frac{3}{2}}=\frac{\sqrt{(a^2-x^2)^3}}{a^3}$

$\therefore$ $\int x\sqrt{a^2-x^2}dx=-\frac{a^3}{3}(1-sin^2 t)^{\frac{3}{2}}+C$

$$=-\frac{1}{3}\sqrt{(a^2-x^2)^3}+C$$

70. $\int x^2\sqrt{a^2-x^2}\,dx=\frac{x}{8}\cdot(2x^2-a^2)\sqrt{a^2-x^2}+\frac{a^4}{8}\cdot arcsin\,\frac{x}{a}+C \qquad (a>0)$

证明：被积函数 $f(x)=x^2\sqrt{a^2-x^2}$的定义域为 $\{x\,|-a<x<a\}$

$\therefore$ 可令$x=a\cdot sint \quad (-\frac{\pi}{2}<t<\frac{\pi}{2})$， 则$x^2\sqrt{a^2-x^2}=a^2\cdot sin^2t\,|\,a\cdot cost\,|$

$\because -\frac{\pi}{2}<t<\frac{\pi}{2}$，$\cos t>0$，$\therefore\ x^2\sqrt{a^2-x^2}=a^3\cdot sin^2t\cdot cost$

$$\therefore \int x^2\sqrt{a^2-x^2}\,dx=\int a^3 sin^2t\cdot cost\,d(a\cdot sint)=a^4\int sin^2t\cdot cos^2t\,dt$$

$$=\frac{a^4}{3}\int 3\cdot sin^2t\cdot cost\cdot cost\,dt$$

$$=\frac{a^4}{3}\int cost\,d\,sin^3t$$

$$=\frac{a^4}{3}\cdot\cos t\cdot sin^3t-\frac{a^4}{3}\int sin^3t\,d\,cost$$

$$=\frac{a^4}{3}\cdot\cos t\cdot sin^3t-\frac{a^4}{3}\int sint\cdot(1-cos^2t)\,d\,cost$$

$$=\frac{a^4}{3}\cdot\cos t\cdot sin^3t-\frac{a^4}{3}\int sint\,d\,cost+\frac{a^4}{3}\int sint\cdot cos^2t\,d\,cost$$

$$=\frac{a^4}{3}\cdot\cos t\cdot sin^3t-\frac{a^4}{3}\int sint\,d\,cost+\frac{a^4}{3}\int sin^2t\cdot cos^2t\,dt$$

移项并整理得：$\int x^2\sqrt{a^2-x^2}\,dx=a^4\int sin^2t\cdot cos^2t\,dt$

$$=\frac{a^4}{4}\cdot\cos t\cdot sin^3t-\frac{a^4}{4}\int sint\,d\,cost \qquad ①$$

$$\because \int sint\,d\,cost=sint\cdot cost-\int cost\,d\,sint$$

$$=sint\cdot cost-\int\cos^2t\,dt$$

$$=sint\cdot cost-\int(1-sin^2t)dt$$

$$=sint\cdot cost-\int dt+\int sin^2t\,dt \qquad ②$$

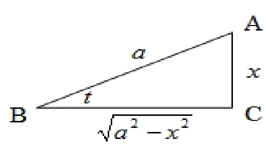
又$\because \int sint\,d\,cost=-\int sin^2t\,dt$ ③

联立②③得：$\int sint\,d\,cost=\frac{1}{2}\cdot sint\cdot cost-\frac{1}{2}\int dt$

$$=\frac{1}{2}\cdot sint\cdot cost-\frac{1}{2}\cdot t+C_1 \qquad ④$$

联立①④得：$\int x^2\sqrt{a^2-x^2}\,dx=\frac{a^4}{4}\cdot\cos t\cdot sin^3t-\frac{a^4}{8}\cdot sint\cdot cost-\frac{a^4}{8}\cdot t+C$

在RtΔABC中，设$\angle B=t$,$|AB|=a$，则$|AC|=x$，$|BC|=\sqrt{a^2-x^2}$



$\therefore\ cost=\frac{\sqrt{a^2-x^2}}{a}$, $sint=\frac{x}{a}$

$$\therefore \int x^2\sqrt{a^2-x^2}\,dx=\frac{a^4}{4}\cdot\frac{\sqrt{a^2-x^2}}{a}\cdot\frac{x^3}{a^3}-\frac{a^4}{8}\cdot\frac{\sqrt{a^2-x^2}}{a}\cdot\frac{x}{a}+\frac{a^4}{8}\cdot arcsin\,\frac{x}{a}+C$$

$$=\frac{x}{8}\cdot(2x^2-a^2)\sqrt{a^2-x^2}+\frac{a^4}{8}\cdot arcsin\,\frac{x}{a}+C$$

71. $\int \frac{\sqrt{a^2-x^2}}{x}dx = \sqrt{a^2-x^2} + a\cdot ln\frac{a-\sqrt{a^2-x^2}}{|x|} + C \qquad (a>0)$

证明：被积函数 $f(x)=\frac{1}{x\sqrt{a^2-x^2}}$ 的定义域为 $\{x\,|\,-a<x<a且x\neq 0\}$

1.当 $-a<x<0$ 时，可设 $x=a\cdot sint \quad (-\frac{\pi}{2}<t<0)$，则 $dx=a\cdot\cos t\,dt$

$\frac{\sqrt{a^2-x^2}}{x}=\frac{|a\cdot\cos t|}{a\cdot sint} \quad \because -\frac{\pi}{2}<t<0\ ,\ \cos t>0 \ \therefore\ \frac{\sqrt{a^2-x^2}}{x}=\frac{\cos t}{sint}$

$$\therefore \int\frac{\sqrt{a^2-x^2}}{x}dx=\int\frac{\cos t}{sint}\cdot a\cdot\cos t\,dt=a\int\frac{\cos^2 t}{sint}dt$$

$$=a\int\frac{1-sin^2t}{sint}dt=a\int\frac{1}{sint}dt-a\int sint\,dt$$

$$=a\int\frac{sint}{sin^2t}dt-a\int sint\,dt=-a\int\frac{1}{1-cos^2t}dcost-a\int sint\,dt$$

$$=-\frac{a}{2}\int(\frac{1}{1+cost}+\frac{1}{1-cost})d\cos t-a\int sint\,dt$$

$$=-\frac{a}{2}\int\frac{1}{1+cost}d(\cos t+1)+\frac{a}{2}\int\frac{1}{cost-1}d(cost-1)-a\int sint\,dt$$

$$=-\frac{a}{2}\cdot ln|1+cost|+\frac{a}{2}\cdot ln|cost-1|+a\cdot\cos t+C_1$$

$$=\frac{a}{2}\cdot ln\left|\frac{cost-1}{1+cost}\right|+a\cdot\cos t+C_1$$

$$=\frac{a}{2}\cdot ln\left|\frac{(cost-1)^2}{1-cos^2t}\cdot(-1)\right|+a\cdot\cos t+C_1$$

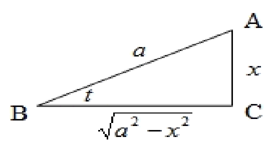
$$=\frac{a}{2}\cdot ln\left|\frac{(cost-1)^2}{sin^2t}\right|+a\cdot\cos t+C_2$$

$$=a\cdot ln\left|\frac{cost-1}{sint}\right|+a\cdot\cos t+C_2$$

$$=a\cdot ln|cott-csct|+a\cdot\cos t+C_2$$

在 Rt ΔABC 中，设 $\angle B=t,|AB|=a$，则 $|AC|=x,|BC|=\sqrt{a^2-x^2}$

$$\therefore\ cott=\frac{\sqrt{a^2-x^2}}{x}\ ,\ csct=\frac{1}{sint}=\frac{a}{x}\ ,\ cost=\frac{\sqrt{a^2-x^2}}{a}$$



$$\therefore \int\frac{\sqrt{a^2-x^2}}{x}dx=a\cdot ln\left|\frac{\sqrt{a^2-x^2}-a}{x}\right|+a\cdot\frac{\sqrt{a^2-x^2}}{a}+C_2$$

$$=a\cdot ln\left|\frac{a-\sqrt{a^2-x^2}}{x}\cdot(-1)\right|+a\cdot\frac{\sqrt{a^2-x^2}}{a}+C_2$$

$$=\frac{1}{a}\cdot ln\left|\frac{a-\sqrt{a^2-x^2}}{x}\right|+a\cdot\frac{\sqrt{a^2-x^2}}{a}+C_3$$

$\because\ a-\sqrt{a^2-x^2}>0$

$$\therefore \int\frac{\sqrt{a^2-x^2}}{x}dx=\sqrt{a^2-x^2}+a\cdot ln\frac{a-\sqrt{a^2-x^2}}{|x|}+C$$

2.当 $0<x<a$ 时，可设 $x=a\cdot sint \quad (0<t<\frac{\pi}{2})$，同理可证

综合讨论 1，2 得：$\int\frac{\sqrt{a^2-x^2}}{x}dx=\sqrt{a^2-x^2}+a\cdot ln\frac{a-\sqrt{a^2-x^2}}{|x|}+C$

72. $\int \frac{\sqrt{a^2-x^2}}{x^2}dx = -\frac{\sqrt{a^2-x^2}}{x} - \arcsin\frac{x}{a} + C \qquad (a>0)$

证明：被积函数 $f(x)=\frac{\sqrt{a^2-x^2}}{x^2}$ 的定义域为 $\{x\,|\,-a<x<a且x\neq 0\}$

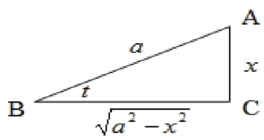
1.当 $-a<x<0$ 时，可设 $x=a\cdot \sin t \quad (-\frac{\pi}{2}<t<0)$，则 $dx=a\cdot\cos t\,dt$，$\frac{\sqrt{a^2-x^2}}{x^2}=\frac{|\,a\cdot\cos t\,|}{a^2\cdot \sin^2 t}$

$\because -\frac{\pi}{2}<t<0$，$\cos t>0$ $\therefore \frac{\sqrt{a^2-x^2}}{x^2}=\frac{\cos t}{a\cdot \sin^2 t}$

$$\begin{aligned}\therefore \int \frac{\sqrt{a^2-x^2}}{x^2}dx &= \int \frac{\cos t}{a\cdot \sin^2 t}\cdot a\cdot \cos t\,dt\\ &= \int \frac{\cos^2 t}{\sin^2 t}dt\\ &= \int \frac{1-\sin^2 t}{\sin^2 t}dt\\ &= \int \csc^2 t dt - \int dt\\ &= -\cot t - t + C\end{aligned}$$

在Rt ΔABC 中，设 $\angle B=t$，$|AB|=a$，则 $|AC|=x$，$|BC|=\sqrt{a^2-x^2}$

$\therefore \cot t=\frac{\sqrt{a^2-x^2}}{x}$



$\therefore \int \frac{\sqrt{a^2-x^2}}{x^2}dx = -\frac{\sqrt{a^2-x^2}}{x} - \arcsin\frac{x}{a} + C$

2.当 $0<x<a$ 时，可设 $x=a\cdot \sin t \quad (0<t<\frac{\pi}{2})$，同理可证

综合讨论 1, 2 得：$\int \frac{\sqrt{a^2-x^2}}{x^2}dx = -\frac{\sqrt{a^2-x^2}}{x} - \arcsin\frac{x}{a} + C$

（九）含有 $\sqrt{\pm a^2+bx+c}\ (a>0)$ 的积分（73~78）

73. $\int\frac{dx}{\sqrt{ax^2+bx+c}}=\frac{1}{\sqrt{a}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+C \qquad (a>0)$

证明:若被积函数 $f(x)=\frac{1}{\sqrt{ax^2+bx+c}}$ 成立，则 $ax^2+bx+c>0$ 恒成立

$$\because\ a>0 \quad \therefore\ \Delta=b^2-4ac>0$$

$$\because ax^2+bx+c=\frac{1}{4a}[(2ax+b)^2+4ac-b^2]$$

$$=\frac{1}{4a}[(2ax+b)^2-(\sqrt{b^2-4ac})^2]$$

$$\therefore\ \int\frac{dx}{\sqrt{ax^2+bx+c}}=2\sqrt{a}\int\frac{1}{\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}}dx$$

$$=\frac{2\sqrt{a}}{2a}\int\frac{1}{\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}}d(2ax+b)$$

$$=\frac{1}{\sqrt{a}}\int\frac{1}{\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}}d(2ax+b)$$

公式45: $\int\frac{dx}{\sqrt{x^2-a^2}}=ln\left|x+\sqrt{x^2-a^2}\right|+C$

$$=\frac{1}{\sqrt{a}}\cdot ln\left|2ax+b+\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}\right|+C$$

$$=\frac{1}{\sqrt{a}}\cdot ln\left|2ax+b+\sqrt{4a\cdot(ax^2+bx+c)}\right|+C$$

$$=\frac{1}{\sqrt{a}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+C$$

74. $\int\sqrt{ax^2+bx+c}\,dx=\frac{2ax+b}{4a}\sqrt{ax^2+bx+c}+\frac{4ac-b^2}{8\sqrt{a^3}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+C \qquad (a>0)$

证明:若被积函数 $f(x)=\sqrt{ax^2+bx+c}$ 成立，则 $ax^2+bx+c>0$ 恒成立

$$\because\ a>0 \quad \therefore\ \Delta=b^2-4ac>0$$

$$\because ax^2+bx+c=\frac{1}{4a}[(2ax+b)^2+4ac-b^2]$$

$$=\frac{1}{4a}[(2ax+b)^2-(\sqrt{b^2-4ac})^2]$$

公式53: $\int\sqrt{x^2-a^2}\,dx=\frac{x}{2}\sqrt{x^2-a^2}-\frac{a^2}{2}\cdot ln\left|x+\sqrt{x^2-a^2}\right|+C$

$$\therefore\ \int\sqrt{ax^2+bx+c}\,dx=\frac{1}{2\sqrt{a}}\int\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}\,dx$$

$$=\frac{1}{2a\cdot2\sqrt{a}}\int\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}\,d(2ax+b)$$

$$=\frac{1}{4a\cdot\sqrt{a}}\cdot\left[\frac{2ax+b}{2}\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}-\frac{b^2-4ac}{2}\cdot ln\left|2ax+b+\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}\right|\right]$$

$$=\frac{1}{4\sqrt{a^3}}\cdot\frac{2ax+b}{2}\cdot2\sqrt{a}\sqrt{ax^2+bx+c}+\frac{4ac-b^2}{8\sqrt{a^3}}\cdot ln\left|2ax+b+\sqrt{(2ax+b)^2-(\sqrt{b^2-4ac})^2}\right|+C$$

$$=\frac{1}{4\sqrt{a^3}}\cdot\frac{2ax+b}{2}\cdot2\sqrt{a}\sqrt{ax^2+bx+c}+\frac{4ac-b^2}{8\sqrt{a^3}}\cdot ln\left|2ax+b+\sqrt{4a\cdot(ax^2+bx+c)}\right|+C$$

$$=\frac{2ax+b}{4a}\cdot\sqrt{ax^2+bx+c}+\frac{4ac-b^2}{8\sqrt{a^3}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+C$$

75. $\int\frac{x}{\sqrt{ax^2+bx+c}}dx=\frac{1}{a}\sqrt{ax^2+bx+c}-\frac{b}{2\sqrt{a^3}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+\mathrm{C} \qquad (a>0)$

证明：$\because d(ax^2+bx+c)=(2ax+b)dx$

$\therefore$ 可将$\int\frac{x}{\sqrt{ax^2+bx+c}}dx$变换成$\int\left[\frac{1}{\sqrt{ax^2+bx+c}}\cdot\left(\frac{2ax+b}{2a}-\frac{b}{2a}\right)\right]dx$

$$\therefore \text{上式}=\frac{1}{2a}\int\frac{1}{\sqrt{ax^2+bx+c}}\cdot(2ax+b)dx-\frac{b}{2a}\int\frac{1}{\sqrt{ax^2+bx+c}}dx$$

$$=\frac{1}{2a}\int(ax^2+bx+c)^{-\frac{1}{2}}d(ax^2+bx+c)-\frac{b}{2a}\int\frac{1}{\sqrt{ax^2+bx+c}}dx$$

$$=\frac{1}{a}\sqrt{ax^2+bx+c}-\frac{b}{2a}\int\frac{1}{\sqrt{ax^2+bx+c}}dx$$

又$\frac{b}{2a}\int\frac{1}{\sqrt{ax^2+bx+c}}dx=\frac{b}{2a}\cdot\frac{1}{\sqrt{a}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+C_1$ （公式73）

$$=\frac{b}{2\sqrt{a^3}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+C_1$$

$$\therefore \int\frac{x}{\sqrt{ax^2+bx+c}}dx=\frac{1}{a}\sqrt{ax^2+bx+c}-\frac{b}{2\sqrt{a^3}}\cdot ln\left|2ax+b+2\sqrt{a}\sqrt{ax^2+bx+c}\right|+\mathrm{C}$$

76. $\int\frac{dx}{\sqrt{c+bx-ax^2}}=\frac{1}{\sqrt{a}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+\mathrm{C} \qquad (a>0)$

证明：若被积函数$f(x)=\frac{1}{\sqrt{c+bx-ax^2}}$成立，则$c+bx-ax^2>0$有解

$$\because a>0 \quad \therefore \Delta=b^2+4ac>0$$

$$\because c+bx-ax^2=\frac{1}{4a}[b^2-(2ax-b)^2]+c$$

$$=\frac{b^2+4ac}{4a}-\frac{(2ax-b)^2}{4a}$$

$$\therefore \int\frac{dx}{\sqrt{c+bx-ax^2}}=2\sqrt{a}\int\frac{1}{\sqrt{(b^2+4ac)^2-(2ax-b)^2}}dx$$

$$=\frac{1}{\sqrt{a}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+\mathrm{C}$$

原题：$\int\frac{dx}{\sqrt{c+bx-ax^2}}=-\frac{1}{\sqrt{a}}\cdot arcisn\frac{2ax-b}{\sqrt{b^2+4ac}}+\mathrm{C}$有误

77. $\int\sqrt{c+bx-ax^2}\,dx=\frac{2ax-b}{8a}\sqrt{c+bx-ax^2}+\frac{b^2+4ac}{8\sqrt{a^3}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+C \qquad (a>0)$

证明:若被积函数 $f(x)=\sqrt{c+bx-ax^2}$ 成立，则 $c+bx-ax^2\geq 0$ 有解

$$\because\ a>0\quad \therefore\ \Delta=b^2+4ac\geq 0$$

$$\because c+bx-ax^2=\frac{1}{4a}[b^2-(2ax-b)^2]+c$$

$$=\frac{b^2+4ac}{4a}-\frac{(2ax-b)^2}{4a}$$

公式67: $\int\sqrt{a^2-x^2}\,dx=\frac{x}{2}\sqrt{a^2-x^2}+\frac{a^2}{2}\cdot arcsin\frac{x}{a}+C$

$$\therefore\ \int\sqrt{c+bx-ax^2}\,dx=\frac{1}{2\sqrt{a}}\int\sqrt{(b^2+4ac)^2-(2ax-b)^2}\,dx$$

$$=\frac{1}{2\sqrt{a}\cdot 2a}\int\sqrt{(\sqrt{b^2+4ac})^2-(2ax-b)^2}\,d(2ax-b)$$

$$=\frac{1}{4\sqrt{a^3}}\left[\frac{2ax-b}{2}\sqrt{(\sqrt{b^2+4ac})^2-(2ax-b)^2}+\frac{b^2+4ac}{2}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}\right]+C$$

$$=\frac{2ax-b}{8\sqrt{a^3}}\sqrt{4a\cdot(c+bx-ax^2)}+\frac{b^2+4ac}{8\sqrt{a^3}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+C$$

$$=\frac{2ax-b}{8a}\sqrt{c+bx-ax^2}+\frac{b^2+4ac}{8\sqrt{a^3}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+C$$

78. $\int\frac{x}{\sqrt{c+bx-ax^2}}dx=-\frac{1}{a}\sqrt{c+bx-ax^2}+\frac{b}{2\sqrt{a^3}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+C \qquad (a>0)$

证明:若被积函数 $f(x)=\frac{x}{\sqrt{c+bx-ax^2}}$ 成立，则 $c+bx-ax^2>0$ 有解

$$\because\ a>0\quad \therefore\ \Delta=b^2+4ac>0$$

$$\because c+bx-ax^2=\frac{1}{4a}[b^2-(2ax-b)^2]+c$$

$$=\frac{1}{4a}\left[b^2+4ac-(2ax-b)^2\right]$$

$$\therefore\ \int\frac{x}{\sqrt{c+bx-ax^2}}dx=2\sqrt{a}\int\frac{x}{\sqrt{(\sqrt{b^2+4ac})^2-(2ax-b)^2}}\,dx$$

公式 61 : $\int\frac{x}{\sqrt{a^2-x^2}}\,dx=-\sqrt{a^2-x^2}+C$

$$=2\sqrt{a}\cdot\frac{1}{2a}\cdot\frac{1}{2a}\int\frac{2ax-b+b}{\sqrt{(\sqrt{b^2+4ac})^2-(2ax-b)^2}}\,d(2ax-b)$$

$$=\frac{1}{2\sqrt{a^3}}\int\frac{2ax-b}{\sqrt{(\sqrt{b^2+4ac})^2-(2ax-b)^2}}\,d(2ax-b)+\frac{b}{2\sqrt{a^3}}\int\frac{1}{\sqrt{(\sqrt{b^2+4ac})^2-(2ax-b)^2}}\,d(2ax-b)$$

$$=-\frac{1}{2\sqrt{a^3}}\sqrt{(\sqrt{b^2+4ac})^2-(2ax-b)^2}+\frac{b}{2\sqrt{a^3}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+C$$

公式59: $\int\frac{dx}{\sqrt{a^2-x^2}}=arcsin\frac{x}{a}+C$

$$=-\frac{1}{2\sqrt{a^3}}\sqrt{4a\cdot(c+bx-ax^2)}+\frac{b}{2\sqrt{a^3}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+C$$

$$=-\frac{1}{a}\sqrt{c+bx-ax^2}+\frac{b}{2\sqrt{a^3}}\cdot arcsin\frac{2ax-b}{\sqrt{b^2+4ac}}+C$$

（十）含有 $\sqrt{\pm\frac{x-a}{x-b}}$ 或 $\sqrt{(x-a)(b-x)}$ 的积分（79~82）

79. $\int\sqrt{\frac{x-a}{x-b}}dx=(x-b)\sqrt{\frac{x-a}{x-b}}+(b-a)\cdot ln(\sqrt{|x-a|}+\sqrt{|x-b|})+C$

证明：$\because \sqrt{\frac{x-a}{x-b}}>0$ 可令 $t=\sqrt{\frac{x-a}{x-b}}\quad(t>0)$，则 $x=\frac{a-bt^2}{1-t^2}$ ，$dx=\frac{2t\cdot(a-b)}{(1-t^2)^2}dt$

$$\therefore \int\sqrt{\frac{x-a}{x-b}}dx=\int t\cdot\frac{2t\cdot(a-b)}{(1-t^2)^2}dt=2(a-b)\int\frac{t^2}{(1-t^2)^2}dt$$

$$=2(b-a)\int\frac{1-t^2+1}{(1-t^2)^2}dt=2(b-a)\int[\frac{1}{1-t^2}-\frac{1}{(1-t^2)^2}]dt$$

$$=2(b-a)\int\frac{1}{1-t^2}dt-2(b-a)\int\frac{1}{(1-t^2)^2}dt=2(a-b)\int\frac{1}{t^2-1}dt+2(a-b)\int\frac{1}{(1-t^2)^2}dt$$

$$=2(a-b)\cdot\frac{1}{2}\cdot ln\left|\frac{t-1}{t+1}\right|+2(a-b)\int\frac{1}{(1-t^2)^2}dt=(a-b)\cdot ln\left|\frac{t-1}{t+1}\right|+2(a-b)\int\frac{1}{(1-t^2)^2}dt$$

对于 $\int\frac{1}{(1-t^2)^2}dt=\int\frac{1}{(t^2-1)^2}dt\qquad(t>0)$

$\therefore$ 可令 $t=sec\,k\quad(0<k<\frac{\pi}{2})$，则 $(t^2-1)^2=tan^4 k$，$d\,sec\,k=sec\,k\cdot tan\,kdk$

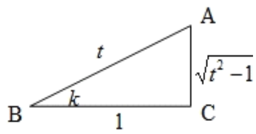
$$\therefore \int\frac{1}{(t^2-1)^2}dt=\int\frac{1}{tan^4 k}\cdot sec\,k\cdot tan\,kdk=\int\frac{sec\,k}{tan^4 k}dk=\int\frac{cos^2 k}{sin^3 k}dk$$

$$=\int\frac{1-sin^2 k}{sin^3 k}dk=\int\frac{1}{sin^3 k}dk-\int\frac{1}{sin\,k}dk=-\frac{1}{2}\cdot\frac{cos\,k}{sin^2 k}+\frac{1}{2}\int\frac{1}{sin\,k}dk-\int\frac{1}{sin\,k}dk$$

$$=-\frac{1}{2}\cdot\frac{cos\,k}{sin^2 k}-\frac{1}{2}\int\frac{1}{sin\,k}dk=-\frac{1}{2}\cdot ln|\,csck-cotk\,|-\frac{1}{2}\cdot\frac{cos\,k}{sin^2 k}$$

在 RtΔABC 中，$\angle B=k$ ，$|BC|=1$ 则 $|AC|=\sqrt{t^2-1}$ ，$|AB|=t$

$\therefore\ csc\,k=\frac{1}{sin\,k}=\frac{t}{\sqrt{t^2-1}}$ ，$cot\,k=\frac{1}{\sqrt{t^2-1}}$ ，$cos\,k=\frac{1}{t}$ ，$sin\,k=\frac{\sqrt{t^2-1}}{t}$



$$\therefore\ \int\sqrt{\frac{x-a}{x-b}}dx=(a-b)\cdot ln\left|\frac{t-1}{t+1}\right|+2(a-b)[-\frac{1}{2}\cdot ln\left|\frac{t-1}{\sqrt{t^2-1}}\right|-\frac{t}{2(t^2-1)}]+C_1$$

$$=(a-b)\cdot ln\left|\frac{t-1}{t+1}\right|-(a-b)\cdot ln\left|\frac{t-1}{\sqrt{t^2-1}}\right|-\frac{(a-b)\cdot t}{t^2-1}+C_1$$

$$=(a-b)\cdot ln\left|\frac{\sqrt{t^2-1}}{t+1}\right|-\frac{(a-b)\cdot t}{(t^2-1)}+C_1$$

将 $t=\sqrt{\frac{x-a}{x-b}}$ 代入上式得：$\therefore\ \int\sqrt{\frac{x-a}{x-b}}dx=(a-b)\cdot ln\left|\frac{\sqrt{\frac{b-a}{|x-b|}}}{\frac{\sqrt{|x-a|}+\sqrt{|x-b|}}{\sqrt{|x-b|}}}\right|-(a-b)\sqrt{\frac{x-a}{x-b}}\cdot\frac{x-b}{b-a}+C_1$

$$=(x-b)\sqrt{\frac{x-a}{x-b}}+(a-b)\,ln\left|\frac{\sqrt{b-a}}{\sqrt{|x-a|}+\sqrt{|x-b|}}\right|+C_1$$

$$=(x-b)\sqrt{\frac{x-a}{x-b}}+(a-b)\,ln\left|\sqrt{b-a}\right|+(b-a)\,ln\left|\sqrt{|x-a|}+\sqrt{|x-b|}\right|+C_1$$

$$=(x-b)\sqrt{\frac{x-a}{x-b}}+(b-a)\cdot ln(\sqrt{|x-a|}+\sqrt{|x-b|})+C$$

80. $\int\sqrt{\frac{x-a}{b-x}}dx=(x-b)\sqrt{\frac{x-a}{b-x}}+(b-a)\cdot arcsin\sqrt{\frac{x-a}{b-a}}+C$

证明：$\because\sqrt{\frac{x-a}{b-x}}>0$ 可令 $t=\sqrt{\frac{x-a}{b-x}}\quad(t>0)$，则$x=\frac{a+bt^2}{1+t^2}$ ，$dx=\frac{2t\cdot(b-a)}{(1+t^2)^2}dt$

$$\therefore\int\sqrt{\frac{x-a}{b-x}}dx=\int t\cdot\frac{2t\cdot(b-a)}{(1+t^2)^2}dt=2(b-a)\int\frac{t^2}{(1+t^2)^2}dt$$

$$=2(b-a)\int\frac{1+t^2-1}{(1+t^2)^2}dt=2(b-a)\int[\frac{1}{1+t^2}-\frac{1}{(1+t^2)^2}]dt$$

$$=2(b-a)\int\frac{1}{1+t^2}dt-2(b-a)\int\frac{1}{(1+t^2)^2}dt=2(b-a)arcsint-2(a-b)\int\frac{1}{(1+t^2)^2}dt$$

$$=2(a-b)\cdot\frac{1}{2}\cdot ln\left|\frac{t-1}{t+1}\right|+2(a-b)\int\frac{1}{(1-t^2)^2}dt=(a-b)\cdot ln\left|\frac{t-1}{t+1}\right|+2(a-b)\int\frac{1}{(1-t^2)^2}dt$$

对于$\int\frac{1}{(1+t^2)^2}dt\quad(t>0)$

$\therefore$ 可令 $t=tank\quad(0<k<\frac{\pi}{2})$，则$(t^2+1)^2=sec^4k$，$dt=sec^2kdk$

$$\therefore\int\frac{1}{(1+t^2)^2}dt=\int\frac{1}{sec^4k}\cdot sec^2kdk=\int\frac{1}{sec^2k}dk=\int cos^2kdk$$

$$=\frac{1}{2}\int(1+cos2k)dk=\frac{1}{2}\int dk+\frac{1}{2}\int cos2kdk$$

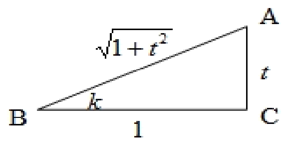
$$=\frac{k}{2}+\frac{1}{4}\cdot sin2k+C_1$$

$$\therefore\int\sqrt{\frac{x-a}{b-x}}dx=2(b-a)k-2(b-a)[\frac{k}{2}+\frac{1}{4}\cdot sin2k]+C_1$$

$$=(b-a)k-(b-a)sink\cdot cosk+C_1$$

在RtΔABC中，$\angle B=k$ ，$|BC|=1$ 则$|AC|=1$ ，$|AB|=\sqrt{t^2+1}$

$\therefore\quad cosk=\frac{1}{\sqrt{t^2+1}}$ ，$sink=\frac{t}{\sqrt{t^2+1}}$



$$\therefore\int\sqrt{\frac{x-a}{b-x}}dx=(b-a)arcsin\frac{t}{\sqrt{t^2+1}}-(b-a)\cdot\frac{1}{\sqrt{t^2+1}}\cdot\frac{t}{\sqrt{t^2+1}}+C_1$$

$$=(b-a)arcsin\frac{t}{\sqrt{t^2+1}}-(b-a)\cdot\frac{t}{t^2+1}+C_1$$

将$t=\sqrt{\frac{x-a}{b-x}}$代入上式得：$\therefore\int\sqrt{\frac{x-a}{b-x}}dx=(b-a)arcsin\left(\sqrt{\frac{b-x}{b-a}}\sqrt{\frac{x-a}{b-x}}\right)-(b-a)\cdot\sqrt{\frac{x-a}{b-x}}\sqrt{\frac{b-x}{b-a}}+C_1$

$$=(b-a)arcsin\sqrt{\frac{x-a}{b-a}}-(b-x)\cdot\sqrt{\frac{x-a}{b-x}}+C_1$$

$$=(b-a)arcsin\sqrt{\frac{x-a}{b-a}}+(x-b)\cdot\sqrt{\frac{x-a}{b-x}}+C$$

81. $\int \frac{dx}{\sqrt{(x-a)(b-x)}} = 2\,arcsin\sqrt{\frac{x-a}{b-a}} + C \qquad (a<b)$

证明: $\int \frac{dx}{\sqrt{(x-a)(b-x)}} = \int \frac{1}{|x-a|} \cdot \sqrt{\frac{x-a}{b-x}}\ dx$

令 $t = \sqrt{\frac{x-a}{b-x}}$，则$x = \frac{a+bt^2}{1+t^2}$，$|x-a| = \left|\frac{(b-a)t^2}{1+t^2}\right|$，$dx = \frac{2t(b-a)}{(1+t^2)^2}dt$

$\because b>a$，$\therefore$ $|x-a| = (b-a)\cdot\frac{t^2}{1+t^2}$

于是 $\int \frac{1}{|x-a|}\cdot\sqrt{\frac{x-a}{b-x}}\ dx = \int \frac{1}{b-a}\cdot\frac{1+t^2}{t^2}\cdot t\cdot\frac{2t\cdot(b-a)}{(1+t^2)^2}dt$

$= 2\int \frac{1}{1+t^2}dt = 2\,arctan\,t + C$ （公式19）

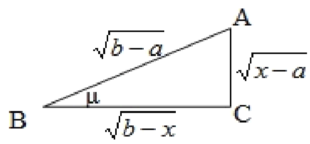
$= 2\,arctan\sqrt{\frac{x-a}{b-x}} + C$

令 $tan\,\mu = \sqrt{\frac{x-a}{b-x}}$, 则 $\mu = arctan\sqrt{\frac{x-a}{b-x}}$

在RtΔABC中，$\angle B = \mu$，$|AC| = \sqrt{x-a}$

$\therefore$ $|BC| = \sqrt{b-x}$，$|AB| = \sqrt{|AC|^2 + |BC|^2} = \sqrt{b-a}$

$\therefore$ $sin\,\mu = \sqrt{\frac{x-a}{b-a}}$，$\therefore$ $\mu = arcsin\sqrt{\frac{x-a}{b-a}}$



$\therefore$ $\int \frac{dx}{\sqrt{(x-a)(b-x)}} = 2\,arcsin\sqrt{\frac{x-a}{b-a}} + C$

82. $\int\sqrt{(x-a)(b-x)}dx=\frac{2x-a-b}{4}\sqrt{(x-a)(b-x)}+\frac{(b-a)^2}{4}\cdot arcsin\sqrt{\frac{x-a}{b-x}}+\text{C}\quad(a<b)$

证明：$\int\sqrt{(x-a)(b-x)}dx=\int|x-a|\sqrt{\frac{b-x}{x-a}}dx$

$\because\sqrt{\frac{b-x}{x-a}}>0$ 可令 $t=\sqrt{\frac{b-x}{x-a}}\quad(t>0)$，则$x=\frac{b+at^2}{1+t^2}$ ，$dx=\frac{2at\cdot(1+t^2)-2t(at^2+b)}{(1+t^2)^2}dt=\frac{2t(a-b)}{(1+t^2)^2}dt$

$$|x-a|=\left|\frac{at^2+b-a-at^2}{1+t^2}\right|=\left|\frac{b-a}{1+t^2}\right|$$

$\because\ a<b\quad\therefore\ |x-a|=\frac{b-a}{1+t^2}$

$$\therefore\ \int\sqrt{(x-a)(b-x)}dx=\int\frac{b-a}{1+t^2}\cdot t\cdot\frac{2t(a-b)}{(1+t^2)^2}dt$$

$$=-2(a-b)^2\int\frac{t^2}{(1+t^2)^3}dt$$

对于$\int\frac{t^2}{(1+t^2)^3}dt\quad(t>0)\ \therefore$ 可令 $t=tan\,k\quad(0<k<\frac{\pi}{2})$，则$(t^2+1)^3=sec^6 k$，$dt=sec^2 kdk$

$$\therefore\ \int\frac{t^2}{(1+t^2)^3}dt=\int\frac{tan^2 k}{sec^6 k}\cdot sec^2 kdk=\int\frac{tan^2 k}{sec^4 k}dk=\int sin^2 k\cdot cos^2 kdk$$

$$=\frac{1}{4}\int(2\,sin\,k\cdot cos\,k)^2 dk=\frac{1}{4}\int sin^2 2k\cdot dk$$

$$=\frac{1}{8}\left[\frac{2k}{2}-\frac{1}{4}\cdot sin4k\right]+C$$

$$=\frac{k}{8}-\frac{1}{32}\cdot sin4k+C$$

$$=\frac{k}{8}-\frac{1}{32}\cdot(4\,sin\,k\cdot cos^3 k-4\,sin^3 k\cdot cos\,k)+C$$

$$=\frac{k}{8}-\frac{1}{8}\cdot sin\,k\cdot cos^3 k+\frac{1}{8}sin^3 k\cdot cos\,k+C$$

联立以上两式得：$\int\sqrt{(x-a)(b-x)}dx=-2(b-a)^2\cdot\frac{1}{8}\cdot(k-sin\,k\cdot cos^3 k+sin^3 k\cdot cos\,k)+\text{C}$

$$=-\frac{(b-a)^2}{4}\cdot(k-sin\,k\cdot cos^3 k+sin^3 k\cdot cos\,k)+\text{C}$$

在RtΔABC中，$\angle\text{B}=k$ ，$|\text{BC}|=1$ 则$|\text{AC}|=t$ ，$|\text{AB}|=\sqrt{t^2+1}$

$\therefore\quad cos\,k=\frac{t}{\sqrt{t^2+1}}$ ，$sin\,k=\frac{1}{\sqrt{t^2+1}}$

$$\therefore\ \int\sqrt{(x-a)(b-x)}dx=-\frac{(b-a)^2}{4}\cdot(arcsin\frac{t}{\sqrt{t^2+1}}-\frac{1}{\sqrt{t^2+1}}\cdot\frac{t^2}{t^2+1}\cdot\frac{t}{\sqrt{t^2+1}}+\frac{1}{t^2+1}\frac{1}{\sqrt{t^2+1}}\cdot\frac{t}{\sqrt{t^2+1}})$$

$$=-\frac{(b-a)^2}{4}\cdot(arcsin\frac{t}{\sqrt{t^2+1}}-\frac{t^3}{(t^2+1)^2}+\frac{t}{(t^2+1)^2})+\text{C}$$

$$=-\frac{(b-a)^2}{4}\cdot(arcsin\frac{t}{\sqrt{t^2+1}}-\frac{t(t^2-1)}{(t^2+1)^2})+\text{C}$$

将$t=\sqrt{\frac{b-x}{x-a}}$代入上式得：$\int\sqrt{(x-a)(b-x)}dx=\frac{2x-a-b}{4}\sqrt{(x-a)(b-x)}+\frac{(b-a)^2}{4}\cdot arcsin\sqrt{\frac{x-a}{b-x}}+\text{C}$

（十一）含有三角函数的积分（83~112）

83. $\int sinx\, dx = -cosx + C$

证明：$\int sinx\, dx = -\int (-sinx)\ dx$

$\because\ (cosx)' = -sinx$即 $cosx$为$-sinx$的原函数

$\therefore\ \int sinx\, dx = -\int dcosx$

$= -cosx + C$

84. $\int cos\,x\, dx = sin\,x + C$

证明：$\because\ (sin\,x)' = cos\,x$即 $sin\,x$为$cos\,x$的原函数

$\therefore\ \int cos\,x\, dx = \int d\,sin\,x$

$= sin\,x + C$

85. $\int tan\,x\, dx = -\,ln|\ cosx\ | + C$

证明：$\int tan\,x\, dx = \int \frac{sinx}{cos\,x}\, dx$

$= -\int \frac{1}{cos\,x}\, d\,cos\,x$

$= -\,ln|\ cosx\ | + C$

86. $\int cot\,x\, dx = ln|\ sin\,x\ | + C$

证明：$\int cot\,x\, dx = \int \frac{cos\,x}{sin\,x}\, dx$

$= \int \frac{1}{sin\,x}\, d\,sin\,x$

$= ln|\ sin\,x\ | + C$

87. $\int sec\,xdx = ln\,|\ tan\,(\frac{\pi}{4} + \frac{x}{2})\ | + \mathrm{C} = ln|sec\,x + tan\,x| + \mathrm{C}$

证明：$\int sec\,xdx = \int \frac{1}{cos\,x} dx = \int \frac{cos\,x}{cos^2\,x} dx$

$= \int \frac{1}{1 - sin^2\,x} d\,sin\,x = \frac{1}{2}\int \frac{1}{1 + sin\,x} d\,sin\,x + \frac{1}{2}\int \frac{1}{1 - sin\,x} d\,sin\,x$

$= \frac{1}{2} \cdot ln\,|\ 1 + sin\,x\ | - \frac{1}{2} \cdot ln\,|\ 1 - sin\,x\ | + \mathrm{C}$

$= \frac{1}{2} \cdot ln\,|\ \frac{1 + sin\,x}{1 - sin\,x}\ | + \mathrm{C} = \frac{1}{2} \cdot ln\ \left| \frac{(1 + sin\,x)^2}{1 - sin^2\,x} \right| + C$

$= \frac{1}{2} \cdot ln \left| \frac{(1 + sin\,x)^2}{cos^2\,x} \right| + C = ln\,|\ \frac{1 + sin\,x}{cos\,x}\ | + \mathrm{C}$

$= ln\ \left| \frac{1}{cos\,x} - \frac{sin\,x}{cox} \right| + C$

$= ln\,|\ sec\,x + tan\,x\ | + \mathrm{C}$

88. $\int csc\,x\,dx = ln\left|\,tan\frac{x}{2}\right| + C = ln\left|\,csc\,x - cot\,x\,\right| + C$

证法1：$\because csc\,x = \frac{1}{sin\,x} = \frac{1}{2\cdot sin\frac{x}{2}\cdot cos\frac{x}{2}} = \frac{sin^2\frac{x}{2}+cos^2\frac{x}{2}}{2\cdot sin\frac{x}{2}\cdot cos\frac{x}{2}} = \frac{1+tan^2\frac{x}{2}}{2\,tan\frac{x}{2}}$

又$\because\ d\,tan\frac{x}{2} = \frac{1}{2}\cdot\frac{1}{cos^2\frac{x}{2}}dx$

$\therefore\ dx = 2\cdot cos^2\frac{x}{2}\,d\,tan\frac{x}{2}$

$$\therefore\ \int csc\,x\,dx = \int\frac{1}{2\cdot sin\frac{x}{2}\cdot cos\frac{x}{2}}\cdot 2\cdot cos^2\frac{x}{2}\,d\,tan\frac{x}{2}$$

$$= \int\frac{1}{tan\frac{x}{2}}\,d\,tan\frac{x}{2}$$

$$= ln\left|\,tan\frac{x}{2}\right| + C$$

$$\because\ tan\frac{x}{2} = \frac{sin\frac{x}{2}}{cos\frac{x}{2}} = \frac{sin^2\frac{x}{2}}{sin\frac{x}{2}\cdot cos\frac{x}{2}} = \frac{2\,sin^2\frac{x}{2}}{2\,sin\frac{x}{2}\cdot cos\frac{x}{2}} = \frac{1-cos\,x}{sin\,x} = csc\,x - cot\,x$$

$$\therefore\ \int csc\,x\,dx = ln\left|\,tan\frac{x}{2}\right| + C = ln\left|\,csc\,x - cot\,x\,\right| + C$$

证法2：$\int csc\,x\,dx = \int\frac{1}{sin t}dt$

$$= \int\frac{sin t}{sin^2 t}dt$$

$$= -\int\frac{1}{1-cos^2 t}\,d\,cos\,t$$

$$= -\frac{1}{2}\int\left(\frac{1}{1+cos t}+\frac{1}{1-cos t}\right)d\,cos t$$

$$= -\frac{1}{2}\int\frac{1}{1+cos t}\,d(cos\,t+1) + \frac{1}{2}\int\frac{1}{1-cos t}\,d(1-cos\,t)$$

$$= -\frac{1}{2}\cdot ln\left|1+cos t\right| + \frac{1}{2}\cdot ln\left|cos t-1\right| + C_1$$

$$= \frac{1}{2}\cdot ln\left|\frac{cos t-1}{1+cos t}\right| + C_1$$

$$= \frac{1}{2}\cdot ln\left|\frac{(1-cos\,t)^2}{1-cos^2 t}\cdot(-1)\right| + C_1$$

$$= \frac{1}{2}\cdot ln\left|\frac{(1-cos\,t)^2}{sin^2 t}\right| + C_2$$

$$= ln\left|\frac{1-cos t}{sin t}\right| + C_2$$

$$= ln\left|\,csc\,x - cot\,x\,\right| + C$$

89. $\int sec^2 x\,dx = tan\,x + C$

证明：$\because$ $(tan\,x)' = sec^2 x$即 $tan\,x$为$sec^2 x$的原函数

$\therefore \int sec^2 x\,dx = \int d\,tan\,t$

$= tan\,x + C$

90. $\int csc^2 x\,dx = -cotx + C$

证明：$\int csc^2 x\,dx = -\int(-csc^2 x)\,dx$

$\because$ $(cotx)' = -csc^2 x$即 $cot\,x$为$-csc^2 x$的原函数

$\therefore \int csc^2 x\,dx = -\int dcotx$

$= -cotx + C$

91. $\int sec\,x \cdot tan\,x\,dx = sec\,x + C$

证明：$\because$ $(sec\,x)' = sec\,x \cdot tan\,x$即 $sec\,x$为$sec\,x \cdot tan\,x$的原函数

$\therefore \int sec\,x \cdot tan\,x\,dx = \int d\,sec\,x$

$= sec\,x + C$

92. $\int cscx \cdot cot\,x\,dx = -csc\,x + C$

证明：$\int cscx \cdot cot\,x\,dx = -\int(-cscx \cdot cot\,x)\,dx$

$\because$ $(csc\,x)' = -cscx \cdot cot\,x$即 $csc\,x$为$-cscx \cdot cot\,x$的原函数

$\therefore \int cscx \cdot cot\,x\,dx = -\int d\,csc\,x$

$= -csc\,x + C$

93. $\int sin^2 x\,dx = \frac{x}{2} - \frac{1}{4} \cdot sin2x + C$

证明：$\int sin^2 x\,dx = \int(\frac{1}{2} - \frac{1}{2} \cdot cos2x)\,dx$

$= \frac{1}{2}\int dx - \frac{1}{4}\int cos2x\,d2x$

$= \frac{x}{2} - \frac{1}{4} sin2x + C$

提示：$sin^2 x = \frac{1-cos2x}{2}$

94. $\int cos^2 x\,dx = \frac{x}{2} + \frac{1}{4} \cdot sin2x + C$

证明：$\int cos^2 x\,dx = \int(\frac{1}{2} + \frac{1}{2} \cdot cos2x)\,dx$

$= \frac{1}{2}\int dx + \frac{1}{4}\int cos2x\,d2x$

$= \frac{x}{2} + \frac{1}{4} sin2x + C$

提示：$cos^2 x = \frac{1+cos2x}{2}$

95. $\int sin^n x\,dx = -\frac{1}{n}\cdot sin^{n-1} x\cdot cos\,x + \frac{n-1}{n}\int sin^{n-2} x\,dx$

证明:$\int sin^n x\,dx = \int sin^{n-1} x\cdot sin\,x\,dx$

$= -\int sin^{n-1} x\,d\,cos\,x$

$= -cos\,x\cdot sin^{n-1} x + \int cos\,x\,d\,sin^{n-1} x$

$= -cos\,x\cdot sin^{n-1} x + \int cos\,x\cdot(n-1)\cdot sin^{n-2} x\cdot cos\,x\,dx$

$= -cos\,x\cdot sin^{n-1} x + (n-1)\int cos^2 x\cdot sin^{n-2} x\,dx$

$= -cos\,x\cdot sin^{n-1} x + (n-1)\int (1-sin^2 x)\cdot sin^{n-2} x\,dx$

$= -cos\,x\cdot sin^{n-1} x + (n-1)\int sin^{n-2} x\,dx - (n-1)\int sin^n x\,dx$

移项并整理得：$n\int sin^n x\,dx = -cos\,x\cdot sin^{n-1} x + (n-1)\int sin^{n-2} x\,dx$

$\therefore \int sin^n x\,dx = -\frac{1}{n}\cdot sin^{n-1} x\cdot cos\,x + \frac{n-1}{n}\int sin^{n-2} x\,dx$

96. $\int cos^n x\,dx = \frac{1}{n}\cdot cos^{n-1} x\cdot sin\,x + \frac{n-1}{n}\int cos^{n-2} x\,dx$

证明:$\int cos^n x\,dx = \int cos^{n-1} x\cdot cos\,x\,dx$

$= \int cos^{n-1} x\,d\,sin\,x$

$= sin\,x\cdot cos^{n-1} x - \int sin\,x\,d\,cos^{n-1} x$

$= sin\,x\cdot cos^{n-1} x + \int sin\,x\cdot(n-1)\cdot cos^{n-2} x\cdot sin\,x\,dx$

$= sin\,x\cdot cos^{n-1} x + (n-1)\int sin^2 x\cdot s\,cos^{n-2} x\,dx$

$= sin\,x\cdot cos^{n-1} x + (n-1)\int (1-cos^2 x)\cdot cos^{n-2} x\,dx$

$= sin\,x\cdot cos^{n-1} x + (n-1)\int cos^{n-2} x\,dx - (n-1)\int cos^n x\,dx$

移项并整理得：$n\int cos^n x\,dx = sin\,x\cdot cos^{n-1} x + (n-1)\int cos^{n-2} x\,dx$

$\therefore \int sin^n x\,dx = \frac{1}{n}\cdot sin\,x\cdot cos^{n-1} x + \frac{n-1}{n}\int cos^{n-2} x\,dx$

97. $\int \frac{dx}{sin^n x} dx = -\frac{1}{n-1} \cdot \frac{cos x}{sin^{n-1} x} + \frac{n-2}{n-1} \int \frac{dx}{sin^{n-2} x}$

证明: $\int \frac{dx}{sin^n x} dx = -\int \frac{1}{sin^{n-2} x} \cdot \frac{1}{-sin^2 x} dx$

$= -\int \frac{1}{sin^{n-2} x} d\, cot x$

$= -\frac{cot x}{sin^{n-2} x} + \int cot x\, d \frac{1}{sin^{n-2} x}$

$= -\frac{cot x}{sin^{n-2} x} + \int cot x \cdot (2-n) \cdot sin^{1-n} x \cdot cos x\, dx$

$= -\frac{cot x}{sin^{n-2} x} + (2-n) \int \frac{cos^2 x}{sin^n x} dx$

$= -\frac{cot x}{sin^{n-2} x} + (2-n) \int \frac{1-sin^2 x}{sin^n x} dx$

$= -\frac{cot x}{sin^{n-2} x} + (2-n) \int \frac{dx}{sin^n x} dx - (2-n) \int \frac{1}{sin^{n-2} x} dx$

移项并整理得: $(n-1) \int \frac{dx}{sin^n x} dx = -\frac{cot x}{sin^{n-2} x} - (2-n) \int \frac{1}{sin^{n-2} x} dx$

$= -\frac{cos x}{sin^{n-1} x} + (n-2) \int \frac{1}{sin^{n-2} x} dx$

$\therefore \int \frac{dx}{sin^n x} dx = -\frac{1}{n-1} \cdot \frac{cos x}{sin^{n-1} x} + \frac{n-2}{n-1} \int \frac{dx}{sin^{n-2} x}$

98. $\int \frac{dx}{cos^n x} = -\frac{1}{n-1} \cdot \frac{sin x}{cos^{n-1} x} + \frac{n-2}{n-1} \int \frac{dx}{cos^{n-2} x}$

证明: $\int \frac{dx}{cos^n x} = \int \frac{1}{cos^{n-2} x} \cdot \frac{1}{cos^2 x} dx$

$= \int \frac{1}{cos^{n-2} x} d\, tan x$

$= \frac{tan x}{cos^{n-2} x} + \int tan x\, d \frac{1}{cos^{n-2} x}$

$= \frac{tan x}{cos^{n-2} x} + \int tan x \cdot (2-n) \cdot cos^{1-n} x \cdot sin x\, dx$

$= \frac{tan x}{cos^{n-2} x} - (n-2) \int \frac{sin^2 x}{cos^n x} dx$

$= \frac{tan x}{cos^{n-2} x} - (n-2) \int \frac{1-cos^2 x}{cos^n x} dx$

$= \frac{sin x}{cos^{n-1} x} - (n-2) \int \frac{dx}{cos^n x} dx + (n-2) \int \frac{1}{cos^{n-2} x} dx$

移项并整理得: $(n-1) \int \frac{dx}{cos^n x} = \frac{sin x}{cos^{n-1} x} + (n-2) \int \frac{1}{cos^{n-2} x} dx$

$= \frac{sin x}{cos^{n-1} x} + (n-2) \int \frac{1}{cos^{n-2} x} dx$

$\therefore \int \frac{dx}{cos^n x} = -\frac{1}{n-1} \cdot \frac{sin x}{cos^{n-1} x} + \frac{n-2}{n-1} \int \frac{dx}{cos^{n-2} x}$

99. $\int cos^m x\cdot sin^n xdx=\frac{1}{m+n}\cdot cos^{m-1}x\cdot sin^{n+1}x+\frac{m-1}{m+n}\int cos^{m-2}x\cdot sin^n xdx$ ①

$=-\frac{1}{m+n}\cdot cos^{m+1}x\cdot sin^{n-1}x+\frac{n-1}{m+n}\int cos^m x\cdot sin^{n-2}xdx$ ②

证明①：$\because d\,sin^{m+n}xdx=(m+n)\cdot sin^{m+n-1}x\cdot cos\,xdx$

$\therefore \int cos^m x\cdot sin^n xdx=\frac{1}{m+n}\int cos^{m-1}x\cdot sin^{1-m}xd\,sin^{m+n}x$

$=\frac{1}{m+n}\cdot cos^{m-1}x\cdot sin^{n+1}x-\frac{1}{m+n}\int sin^{m+n}xd(cos^{m-1}x\cdot sin^{1-m}x)$

$\because d(cos^{m-1}x\cdot sin^{1-m}x)=[-(m-1)\cdot cos^{m-2}x\cdot sin\,x\cdot sin^{1-m}x+(1-m)\cdot sin^{1-m-1}x\cdot cos\,x\cdot cos^{m-1}x]dx$

$=[(1-m)\cdot sin^{-m}x\cdot cos^m x\cdot(sin^2 x\cdot cos^{-2}x+1)]dx$

$=[(1-m)\cdot sin^{-m}x\cdot cos^m x\cdot(\frac{sin^2 x+cos^2 x}{cos^2 x})]dx$

$=[(1-m)\cdot sin^{-m}x\cdot cos^{m-2}x]dx$

$\therefore -\frac{1}{m+n}\int sin^{m+n}xd(cos^{m-1}x\cdot sin^{1-m}x)=\frac{m-1}{m+n}\int cos^{m-2}x\cdot sin^n xdx$

$\therefore \int cos^m x\cdot sin^n xdx=\frac{1}{m+n}\cdot cos^{m-1}x\cdot sin^{n+1}x+\frac{m-1}{m+n}\int cos^{m-2}x\cdot sin^n xdx$

证明②：$\because d\,cos^{m+n}x=-(m+n)\cdot cos^{m+n-1}x\cdot sin\,xdx$

$\therefore \int cos^m x\cdot sin^n xdx=\frac{-1}{m+n}\int cos^{1-n}x\cdot sin^{n-1}xd\,cos^{m+n}x$

$=\frac{-1}{m+n}\cdot sin^{n-1}x\cdot cos^{m+1}x+\frac{1}{m+n}\int cos^{m+n}xd(sin^{n-1}x\cdot cos^{1-n}x)$

$\because d(sin^{n-1}x\cdot cos^{1-n}x)=[(n-1)\cdot sin^{n-2}x\cdot cos\,x\cdot cos^{1-n}x-(1-n)\cdot cos^{1-n-1}x\cdot sin\,x\cdot sin^{n-1}x]dx$

$=[(n-1)\cdot cos^{-n}x\cdot sin^n x\cdot(sin^{-2}x\cdot cos^2 x+1)]dx$

$=[(n-1)\cdot cos^{-n}x\cdot sin^n x\cdot(\frac{sin^2 x+cos^2 x}{sin^2 x})]dx$

$=[(n-1)\cdot cos^{-n}x\cdot sin^{n-2}x]dx$

$\therefore \frac{1}{m+n}\int cos^{m+n}xd(sin^{n-1}x\cdot cos^{1-n}x)=\frac{n-1}{m+n}\int cos^m x\cdot sin^{n-2}xdx$

$\therefore \int cos^m x\cdot sin^n xdx=-\frac{1}{m+n}\cdot cos^{m+1}x\cdot sin^{n-1}x+\frac{n-1}{m+n}\int cos^m x\cdot sin^{n-2}xdx$

100. $\int sin\,ax \cdot cos\,bx\,dx = -\frac{1}{2(a+b)} \cdot cos(a+b)x - \frac{1}{2(a-b)} \cdot cos(a-b)x + \mathrm{C}$

证明: $\int sin\,ax \cdot cos\,bx\,dx = \int \frac{1}{2}[sin\,(a+b)x + sin(a-b)x]dx$ 提示: $sin\ \alpha\ cos\ \beta = \frac{1}{2}[sin\ (\alpha+\beta) + sin\ (\alpha-\beta)]$

$$= \frac{1}{2}\int sin\,(a+b)x\,dx \frac{1}{2}\int sin(a-b)xdx$$

$$= \frac{1}{2(a+b)}\int sin\,(a+b)x\,d(a+b)x + \frac{1}{2(a-b)}\int sin\,(a-b)x\,d(a-b)x$$

$$= -\frac{1}{2(a+b)} \cdot cos(a+b)x - \frac{1}{2(a-b)} \cdot cos(a-b)x$$

101. $\int sin\,ax \cdot sin\,bx\,dx = -\frac{1}{2(a+b)} \cdot sin\,(a+b)x + \frac{1}{2(a-b)} \cdot sin\,(a-b)x + \mathrm{C}$

证明: $\int sin\,ax \cdot sin\,bx\,dx = \int \frac{1}{2}[cos\,(a-b)x - cos(a+b)x]dx$ 提示: $sin\ \alpha\ sin\ \beta = -\frac{1}{2}[cos\,(\alpha+\beta) + cos\ (\alpha-\beta)]$

$$= \frac{1}{2}\int cos\,(a-b)x\,dx - \frac{1}{2}\int cos\,(a+b)x\,dx$$

$$= \frac{1}{2(a-b)}\int cos\,(a-b)x\,d(a-b)x - \frac{1}{2(a+b)}\int cos\,(a+b)x\,d(a+b)x$$

$$= \frac{1}{2(a-b)} \cdot sin\,(a-b)x - \frac{1}{2(a+b)} \cdot sin\,(a+b)x + \mathrm{C}$$

102. $\int cos\,ax \cdot cos\,bx\,dx = \frac{1}{2(a+b)} \cdot sin\,(a+b)x + \frac{1}{2(a-b)} \cdot sin\,(a-b)x + \mathrm{C}$

证明: $\int cos\,ax \cdot cos\,bx\,dx = \int \frac{1}{2}[cos\,(a+b)x + cos(a-b)x]dx$ 提示: $cos\,\alpha\,cos\,\beta = \frac{1}{2}[cos\,(\alpha+\beta) + cos\,(\alpha-\beta)]$

$$= \frac{1}{2}\int cos\,(a+b)x\,dx + \frac{1}{2}\int cos\,(a-b)x\,dx$$

$$= \frac{1}{2(a+b)}\int cos\,(a+b)x\,d(a+b)x + \frac{1}{2(a-b)}\int cos\,(a-b)x\,d(a-b)x$$

$$= \frac{1}{2(a+b)} \cdot sin\,(a+b)x + \frac{1}{2(a-b)} \cdot sin\,(a-b)x + \mathrm{C}$$

103. $\int \frac{dx}{a+b\cdot \sin x}=\frac{2}{\sqrt{a^2-b^2}}\cdot \arctan\frac{a\cdot \tan\frac{x}{2}+b}{\sqrt{a^2-b^2}}+C \qquad (a^2>b^2)$

证明：令$t=\tan\frac{x}{2}$，则 $\sin x=2\cdot \sin\frac{x}{2}\cdot \cos\frac{x}{2}=\frac{2\cdot \tan\frac{x}{2}}{1+\tan^2\frac{x}{2}}=\frac{2t}{1+t^2}$

$$dt=(\tan\frac{x}{2})dx=\frac{1}{2}\cdot \sec^2\frac{x}{2}dx=\frac{1}{2}(1+\tan^2\frac{x}{2})\,dx=\frac{1}{2}(1+t^2)\,dx$$

$$\therefore\ dx=\frac{2}{1+t^2}dt\ ,\ a+b\cdot \sin x=a+\frac{2bt}{1+t^2}=\frac{a(1+t^2)+2bt}{1+t^2}$$

$$\therefore \int \frac{dx}{a+b\cdot \sin x}=\int \frac{1+t^2}{a(1+t^2)+2bt}\cdot \frac{2}{1+t^2}dt$$

$$=2\int \frac{1}{a t^2+2bt+a}dt$$

$$=2\int \frac{1}{a(t+\frac{b}{a})^2-\frac{b^2}{a}+a}dt$$

$$=2a\int \frac{1}{(at+b)^2+(a^2-b^2)}dt$$

$$=2\int \frac{1}{(at+b)^2+(a^2-b^2)}d(at+b)$$

当$a^2>b^2$，即$a^2-b^2>0$时

$$2\int \frac{1}{(at+b)^2+(a^2-b^2)}d(at+b)=2\int \frac{1}{(at+b)^2+(\sqrt{a^2-b^2})^2}d(at+b)$$

公式19：$\int \frac{dx}{x^2+a^2}=\frac{1}{a}\cdot \arctan\frac{x}{a}+C$

$$=\frac{2}{\sqrt{a^2-b^2}}\cdot \arctan\frac{at+b}{\sqrt{a^2-b^2}}+C$$

将$t=\tan\frac{x}{2}$代入上式得：$\int \frac{dx}{a+b\sin x}=\frac{2}{\sqrt{a^2-b^2}}\cdot \arctan\frac{a\cdot \tan\frac{x}{2}+b}{\sqrt{a^2-b^2}}+C$

104. $\int \frac{dx}{a+b\sin x}=\frac{1}{\sqrt{b^2-a^2}}\cdot \ln\left|\frac{a\cdot\tan\frac{x}{2}+b-\sqrt{b^2-a^2}}{a\cdot\tan\frac{x}{2}+b+\sqrt{b^2-a^2}}\right|+\mathrm{C}\qquad (a^2<b^2)$

证明:令$t=\tan\frac{x}{2}$，则 $\sin x=2\cdot\sin\frac{x}{2}\cdot\cos\frac{x}{2}=\frac{2\cdot\tan\frac{x}{2}}{1+\tan^2\frac{x}{2}}=\frac{2t}{1+t^2}$

$$dt=(\tan\frac{x}{2})dx=\frac{1}{2}\cdot\sec^2\frac{x}{2}dx=\frac{1}{2}(1+\tan^2\frac{x}{2})\,dx=\frac{1}{2}(1+t^2)\,dx$$

$\therefore\ dx=\frac{2}{1+t^2}dt$，$a+b\sin x=a+\frac{2bt}{1+t^2}=\frac{a(1+t^2)+2bt}{1+t^2}$

$$\therefore\ \int\frac{dx}{a+b\sin x}=\int\frac{1+t^2}{a(1+t^2)+2bt}\cdot\frac{2}{1+t^2}dt$$

$$=2\int\frac{1}{at^2+2bt+a}dt$$

$$=2\int\frac{1}{a(t+\frac{b}{a})^2-\frac{b^2}{a}+a}dt$$

$$=2a\int\frac{1}{(at+b)^2+(a^2-b^2)}dt$$

$$=2\int\frac{1}{(at+b)^2+(a^2-b^2)}d(at+b)$$

当$a^2<b^2$,即$a^2-b^2<0$时

$$2\int\frac{1}{(at+b)^2+(a^2-b^2)}d(at+b)=2\int\frac{1}{(at+b)^2-(b^2-a^2)}d(at+b)$$

$$=2\int\frac{1}{(at+b)^2-(\sqrt{b^2-a^2})^2}d(at+b)$$

公式 21: $\int\frac{dx}{x^2-a^2}=\frac{1}{2a}\cdot\ln\left|\frac{x-a}{x+a}\right|+\mathrm{C}$

$$=2\times\frac{1}{2\sqrt{b^2-a^2}}\cdot\ln\left|\frac{at+b-\sqrt{b^2-a^2}}{at+b+\sqrt{b^2-a^2}}\right|+C$$

将$t=\tan\frac{x}{2}$代入上式得: $\int\frac{dx}{a+b\sin x}=\frac{1}{\sqrt{b^2-a^2}}\cdot\ln\left|\frac{a\cdot\tan\frac{x}{2}+b-\sqrt{b^2-a^2}}{a\cdot\tan\frac{x}{2}+b+\sqrt{b^2-a^2}}\right|+\mathrm{C}$

105. $\int \frac{dx}{a+b\cdot \cos x}=\frac{2}{a+b}\cdot\sqrt{\frac{a+b}{a-b}}\arctan\left(\sqrt{\frac{a-b}{a+b}}\cdot\tan\frac{x}{2}\right)+C \qquad (a^2>b^2)$

证明：令$t=\tan\frac{x}{2}$，则 $\cos x=\frac{1-\tan^2\frac{x}{2}}{1+\tan^2\frac{x}{2}}=\frac{1-t^2}{1+t^2}$

$$\therefore\ a+b\cdot\cos x=a+b\cdot\frac{1-t^2}{1+t^2}=\frac{(a+b)+t^2(a-b)}{1+t^2}$$

$$\because\ dt=d\tan\frac{x}{2}=\frac{1}{2}\cdot\sec^2\frac{x}{2}dx=\frac{1}{2\cos^2\frac{x}{2}}dx=\frac{1}{1+\cos x}dx=\frac{1+t^2}{2}dx$$

$$\therefore\ dx=\frac{2}{1+t^2}dt$$

提示：$\cos^2\theta=\frac{1+\cos 2\theta}{2}$

$$\therefore\ \int\frac{dx}{a+b\cdot\cos x}=\int\frac{2}{(a+b)+t^2(a-b)}dt$$

当$|a|>|b|$，即$a^2>b^2$时

$$\int\frac{2}{(a+b)+t^2(a-b)}dt=\frac{2}{a-b}\int\frac{1}{\left(\sqrt{\frac{a+b}{a-b}}\right)^2+t^2}dt$$

公式19：$\int\frac{dx}{x^2+a^2}=\frac{1}{a}\cdot\arctan\frac{x}{a}+C$

$$=\frac{2}{a-b}\cdot\sqrt{\frac{a-b}{a+b}}\cdot\arctan\left(\sqrt{\frac{a-b}{a+b}}\cdot t\right)+C$$

$$=\frac{2}{a-b}\cdot\sqrt{\frac{a-b}{a+b}}\cdot\arctan\left(\sqrt{\frac{a-b}{a+b}}\cdot t\right)+C$$

$$=2\sqrt{\frac{1}{(a+b)\cdot(a-b)}}\cdot\arctan\left(\sqrt{\frac{a-b}{a+b}}\cdot t\right)+C$$

$$=\frac{2}{a+b}\cdot\sqrt{\frac{a+b}{a-b}}\cdot\arctan\left(\sqrt{\frac{a-b}{a+b}}\cdot t\right)+C$$

将$t=\tan\frac{x}{2}$代入上式得：$\int\frac{dx}{a+b\cdot\cos x}=\frac{2}{a+b}\cdot\sqrt{\frac{a+b}{a-b}}\arctan\left(\sqrt{\frac{a-b}{a+b}}\cdot\tan\frac{x}{2}\right)+C$

106. $\int \frac{dx}{a+b\cdot cos x} = \frac{1}{a+b}\cdot\sqrt{\frac{a+b}{b-a}}\cdot ln\left|\frac{tan\frac{x}{2}+\sqrt{\frac{a+b}{b-a}}}{tan\frac{x}{2}-\sqrt{\frac{a+b}{b-a}}}\right| + C \qquad (a^2 < b^2)$

证明：令$t = tan\frac{x}{2}$，则 $cos x = \frac{1-tan^2\frac{x}{2}}{1+tan^2\frac{x}{2}} = \frac{1-t^2}{1+t^2}$

$$\therefore\ a+b\cdot cos x = a+b\cdot\frac{1-t^2}{1+t^2} = \frac{(a+b)+t^2(a-b)}{1+t^2}$$

$$\because\ dt = d\,tan\frac{x}{2} = \frac{1}{2}\cdot sec^2\frac{x}{2}dx = \frac{1}{2cos^2\frac{x}{2}}dx = \frac{1}{1+cos x}dx = \frac{1+t^2}{2}dx$$

$$\therefore\ dx = \frac{2}{1+t^2}dt$$

提示：$cos^2\theta = \frac{1+cos 2\theta}{2}$

$$\therefore\ \int\frac{dx}{a+b\cdot cos x} = \int\frac{2}{(a+b)+t^2(a-b)}dt$$

当 $a^2 < b^2$，即$|a|<|b|$，$\therefore\ b-a>0$

$$\int\frac{2}{(a+b)+t^2(a-b)}dt = \int\frac{2}{(a+b)-t^2(b-a)}dt$$

$$= \frac{2}{b-a}\int\frac{1}{\left(\sqrt{\frac{a+b}{b-a}}\right)^2 - t^2}dt = \frac{2}{a-b}\int\frac{1}{t^2-\left(\sqrt{\frac{a+b}{b-a}}\right)^2}dt$$

$$= \frac{2}{a-b}\cdot\frac{1}{2}\cdot\sqrt{\frac{b-a}{a+b}}\cdot ln\left|\frac{t-\sqrt{\frac{a+b}{b-a}}}{t+\sqrt{\frac{a+b}{b-a}}}\right| + C = \frac{1}{a-b}\cdot\sqrt{\frac{b-a}{a+b}}\cdot ln\left|\frac{t-\sqrt{\frac{a+b}{b-a}}}{t+\sqrt{\frac{a+b}{b-a}}}\right| + C$$

公式 21：$\int\frac{dx}{x^2-a^2} = \frac{1}{2a}\cdot ln\left|\frac{x-a}{x+a}\right| + C$

$$= (-1)\sqrt{\frac{1}{(a+b)\cdot(b-a)}}\cdot ln\left|\frac{t-\sqrt{\frac{a+b}{b-a}}}{t+\sqrt{\frac{a+b}{b-a}}}\right| + C = -\frac{1}{a+b}\cdot\sqrt{\frac{a+b}{b-a}}\cdot ln\left|\frac{t-\sqrt{\frac{a+b}{b-a}}}{t+\sqrt{\frac{a+b}{b-a}}}\right| + C$$

$$= \frac{1}{a+b}\cdot\sqrt{\frac{a+b}{b-a}}\cdot ln\left|\frac{t+\sqrt{\frac{a+b}{b-a}}}{t-\sqrt{\frac{a+b}{b-a}}}\right| + C$$

将$t = tan\frac{x}{2}$代入上式得：$\int\frac{dx}{a+b\cdot cos x} = \frac{1}{a+b}\cdot\sqrt{\frac{a+b}{b-a}}\cdot ln\left|\frac{tan\frac{x}{2}+\sqrt{\frac{a+b}{b-a}}}{tan\frac{x}{2}-\sqrt{\frac{a+b}{b-a}}}\right| + C$

107. $\int \frac{dx}{a^2 \cos^2 x + b^2 \sin^2 x} = \frac{1}{ab} \cdot \arctan\left(\frac{b}{a} \cdot \tan x\right) + C$

证明：$\int \frac{dx}{a^2 \cos^2 x + b^2 \sin^2 x} = \int \frac{1}{\cos^2 x} \cdot \frac{1}{a^2 + b^2 \tan^2 x} dx$

$$= \int \frac{1}{a^2 + b^2 \tan^2 x} d \tan x$$

$$= \frac{1}{b^2} \int \frac{1}{(\frac{a^2}{b^2} + \tan^2 x)} d \tan x$$

$$= \frac{1}{b^2} \int \frac{1}{(\frac{a}{b})^2 + \tan^2 x)} d \tan x$$

公式19：$\int \frac{dx}{x^2 + a^2} = \frac{1}{a} \cdot \arctan \frac{x}{a} + C$

$$= \frac{1}{b^2} \cdot \frac{b}{a} \cdot \arctan\left(\frac{b}{a} \cdot \tan x\right) + C$$

$$= \frac{1}{ab} \cdot \arctan\left(\frac{b}{a} \cdot \tan x\right) + C$$

108. $\int \frac{dx}{a^2 \cos^2 x - b^2 \sin^2 x} = \frac{1}{2ab} \cdot \ln\left|\frac{b \cdot \tan x + a}{b \cdot \tan x - a}\right| + C$

证明：$\int \frac{dx}{a^2 \cos^2 x - b^2 \sin^2 x} = \int \frac{1}{\cos^2 x} \cdot \frac{1}{a^2 - b^2 \tan^2 x} dx$

$$= \int \frac{1}{a^2 - b^2 \tan^2 x} d \tan x$$

$$= \frac{1}{b} \int \frac{1}{a^2 - (b \cdot \tan x)^2} d (b \cdot \tan x)$$

$$= -\frac{1}{b} \int \frac{1}{(b \cdot \tan x)^2 - a^2} d (b \cdot \tan x)$$

公式 21：$\int \frac{dx}{x^2 - a^2} = \frac{1}{2a} \cdot \ln\left|\frac{x-a}{x+a}\right| + C$

$$= -\frac{1}{b} \cdot \frac{1}{2a} \cdot \ln\left|\frac{b \cdot \tan x - a}{b \cdot \tan x + a}\right| + C$$

$$= -\frac{1}{2ab} \cdot \ln\left|\frac{b \cdot \tan x - a}{b \cdot \tan x + a}\right| + C$$

提示：$\log_a b^{-1} = -\log_a b$

$$= \frac{1}{2ab} \cdot \ln\left|\frac{b \cdot \tan x + a}{b \cdot \tan x - a}\right| + C$$

109. $\int x \cdot \sin ax\, dx = \frac{1}{a^2} \cdot \sin ax - \frac{1}{a} \cdot x \cdot \cos ax + C$

证明：$\int x \cdot \sin ax\, dx = -\frac{1}{a}\int x\, d\cos ax$

$$= -\frac{1}{a} \cdot x \cdot \cos ax + \frac{1}{a}\int \cos ax\, dx$$

$$= -\frac{1}{a} \cdot x \cdot \cos ax + \frac{1}{a^2}\int \cos ax\, dax$$

$$= -\frac{1}{a} \cdot x \cdot \cos ax + \frac{1}{a^2} \cdot \sin ax + C$$

110. $\int x^2 \cdot \sin ax\, dx = -\frac{1}{a} \cdot x^2 \cdot \cos ax + \frac{2}{a^2} \cdot x \cdot \sin ax + \frac{2}{a^3} \cdot \cos ax + C$

证明：$\int x^2 \cdot \sin ax\, dx = -\frac{1}{a}\int x^2\ d\cos ax$

$$= -\frac{1}{a} \cdot x^2 \cdot \cos ax + \frac{1}{a}\int \cos ax\, dx^2$$

$$= -\frac{1}{a} \cdot x^2 \cdot \cos ax + \frac{2}{a}\int x \cdot \cos ax\, dx$$

$$= -\frac{1}{a} \cdot x^2 \cdot \cos ax + \frac{2}{a^2} \cdot \int x\, d\sin ax$$

$$= -\frac{1}{a} \cdot x^2 \cdot \cos ax + \frac{2}{a^2} \cdot x \cdot \sin ax - \frac{2}{a^3} \cdot \int \sin ax\, dax$$

$$= -\frac{1}{a} \cdot x^2 \cdot \cos ax + \frac{2}{a^2} \cdot x \cdot \sin ax + \frac{2}{a^3} \cdot \cos ax$$

111. $\int x \cdot \cos ax\, dx = \frac{1}{a^2} \cdot \cos ax - \frac{1}{a} \cdot x \cdot \sin ax + C$

证明：$\int x \cdot \cos ax\, dx = \frac{1}{a}\int x\, d\sin ax$

$$= \frac{1}{a} \cdot x \cdot \sin ax - \frac{1}{a}\int \sin ax\, dx$$

$$= \frac{1}{a} \cdot x \cdot \sin ax - \frac{1}{a^2}\int \sin ax\, dax$$

$$= \frac{1}{a} \cdot x \cdot \sin ax + \frac{1}{a^2} \cdot \cos ax + C$$

112. $\int x^2 \cdot \cos ax\, dx = \frac{1}{a} \cdot x^2 \cdot \sin ax + \frac{2}{a^2} \cdot x \cdot \cos ax - \frac{2}{a^3} \cdot \sin ax + C$

证明：$\int x^2 \cdot \cos ax\, dx = \frac{1}{a}\int x^2\ d\sin ax$

$$= \frac{1}{a} \cdot x^2 \cdot \sin ax - \frac{1}{a}\int \sin ax\, dx^2$$

$$= \frac{1}{a} \cdot x^2 \cdot \sin ax + \frac{2}{a}\int x \cdot \sin ax\, dx$$

$$= \frac{1}{a} \cdot x^2 \cdot \sin ax - \frac{2}{a^2} \cdot \int x\, d\cos ax$$

$$= \frac{1}{a} \cdot x^2 \cdot \sin ax + \frac{2}{a^2} \cdot x \cdot \cos ax - \frac{2}{a^3} \cdot \int \cos ax\, dax$$

$$= \frac{1}{a} \cdot x^2 \cdot \sin ax + \frac{2}{a^2} \cdot x \cdot \cos ax - \frac{2}{a^3} \cdot \sin ax + C$$

（十二）含有反三角函数的积分（其中 $a>0$）（113~121）

113. $\int arcsin\frac{x}{a}dx = x\cdot arcsin\frac{x}{a} + \sqrt{a^2-x^2} + C \qquad (a>0)$

证明：$\int arcsin\frac{x}{a}dx = x\cdot arcsin\frac{x}{a} - \int x\, d\ arcsin\frac{x}{a}$

$$= x\cdot arcsin\frac{x}{a} - \int x\cdot\frac{1}{\sqrt{1-(\frac{x}{a})^2}}\cdot\frac{1}{a}dx$$

$$= x\cdot arcsin\frac{x}{a} - \int\frac{x}{\sqrt{a^2-x^2}}dx$$

$$= x\cdot arcsin\frac{x}{a} - \frac{1}{2}\int\frac{1}{\sqrt{a^2-x^2}}dx^2$$

$$= x\cdot arcsin\frac{x}{a} + \frac{1}{2}\int(a^2-x^2)^{-\frac{1}{2}}d(a^2-x^2)$$

$$= x\cdot arcsin\frac{x}{a} + \frac{1}{2}\cdot\frac{1}{1-\frac{1}{2}}\cdot(a^2-x^2)^{1-\frac{1}{2}} + C$$

$$= x\cdot arcsin\frac{x}{a} + \sqrt{a^2-x^2} + C$$

114. $\int x\cdot arcsin\frac{x}{a}dx = (\frac{x^2}{2}-\frac{a^2}{4})\cdot arcsin\frac{x}{a} + \frac{x}{4}\sqrt{a^2-x^2} + C \qquad (a>0)$

证明：令 $t = arcsin\frac{x}{a}$，则 $x = a\cdot sin\,t$

$$\therefore \int x\cdot arcsin\frac{x}{a}dx = \int a\cdot sin\,t\cdot t\,d(a\cdot sin\,t) = a^2\int t\cdot sin\,t\cdot cos\,t\,dt$$

$$= \frac{a^2}{2}\int t\cdot sin2t\,dt = -\frac{a^2}{4}\int t\,d\,cos2t$$

$$= -\frac{a^2}{4}\cdot t\cdot cos2t + \frac{a^2}{4}\int cos2t\,dt$$

$$= -\frac{a^2}{4}\cdot t\cdot cos2t + \frac{a^2}{8}\int cos2t\,d2t$$

$$= -\frac{a^2}{4}\cdot t\cdot cos2t + \frac{a^2}{8}\cdot sin2t + C$$

$$= -\frac{a^2}{4}\cdot t\cdot(2cos^2t-1) + \frac{a^2}{4}\cdot sin\,t\cdot cos\,t + C$$

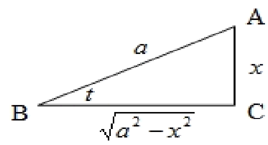
$$= -\frac{a^2}{2}\cdot t\cdot cos^2t + \frac{a^2}{4}\cdot t + \frac{a^2}{4}\cdot sin\,t\cdot cos\,t + C$$

提示：$sin2x = 2\cdot sin\,x\cdot cos\,x$

$cos2x = cos^2x - sin^2x$

$= 2cos^2x - 1$

在Rt ΔABC中，可设$\angle B = t$，$|AB| = a$，则$|AC| = x$，$|BC| = \sqrt{a^2-x^2}$



$\therefore\ cos\,t = \frac{\sqrt{a^2-x^2}}{a}$，$sin\,t = \frac{x}{a}$

$$\therefore \int x\cdot arcsin\frac{x}{a}dx = -\frac{a^2}{2}\cdot arcsin\frac{x}{a}\cdot\frac{a^2-x^2}{a^2} + \frac{a^2}{4}\cdot arcsin\frac{x}{a} + \frac{a^2}{4}\cdot\frac{x}{a}\cdot\frac{\sqrt{a^2-x^2}}{a} + C$$

$$= \frac{x^2-a^2}{2}\cdot arcsin\frac{x}{a} + \frac{a^2}{4}\cdot arcsin\frac{x}{a} + \frac{x}{4}\cdot\sqrt{a^2-x^2} + C$$

$$= (\frac{x^2}{2}-\frac{a^2}{4})\cdot arcsin\frac{x}{a} + \frac{x}{4}\sqrt{a^2-x^2} + C$$

115. $\int x^2 \cdot arcsin\frac{x}{a}dx = \frac{x^3}{3}\cdot arcsin\frac{x}{a} + \frac{1}{9}(x^2+2a^2)\sqrt{a^2-x^2} + C \qquad (a>0)$

证明：令$t = arcsin\frac{x}{a}$，则 $x = a\cdot sin t$

$$\therefore \int x^2 \cdot arcsin\frac{x}{a}dx = \int a^2 \cdot sin^2 t \cdot t\, d(a\cdot sin t) = a^3\int t\cdot sin^2 t\cdot cos t\, dt$$

$$= \frac{a^3}{3}\int t\, d\, sin^3 t$$

$$= \frac{a^3}{3}\cdot t\cdot sin^3 t - \frac{a^3}{3}\int sin^3 t\, dt$$

$$= \frac{a^3}{3}\cdot t\cdot sin^3 t - \frac{a^3}{3}\int sin t\,(1-cos^2 t)\, dt$$

$$= \frac{a^3}{3}\cdot t\cdot sin^3 t - \frac{a^3}{3}\int sin t\, dt + \frac{a^3}{3}\int sin t\cdot cos^2 t\, dt$$

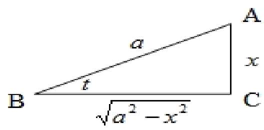
$$= \frac{a^3}{3}\cdot t\cdot sin^3 t + \frac{a^3}{3}\cdot cos t - \frac{a^3}{3}\int cos^2 t\, d\, cos t$$

$$= \frac{a^3}{3}\cdot t\cdot sin^3 t + \frac{a^3}{3}\cdot cos t - \frac{a^3}{3}\cdot\frac{1}{1+2}\cdot cos^3 t + C$$

$$= \frac{a^3}{3}\cdot t\cdot sin^3 t + \frac{a^3}{3}\cdot cos t - \frac{a^3}{9}\cdot cos^3 t + C$$

在Rt ΔABC中，可设$\angle B = t, |AB| = a$，则$|AC| = x, |BC| = \sqrt{a^2-x^2}$

$\therefore\ cos t = \frac{\sqrt{a^2-x^2}}{a}$，$sin t = \frac{x}{a}$



$$\therefore \int x^2\cdot arcsin\frac{x}{a}dx = \frac{a^3}{3}\cdot arcsin\frac{x}{a}\cdot\frac{x^3}{a^3} + \frac{a^3}{3}\cdot\frac{\sqrt{a^2-x^2}}{a} - \frac{a^3}{9}\cdot\frac{a^2-x^2}{a^3}\cdot\sqrt{a^2-x^2} + C$$

$$= \frac{x^3}{3}\cdot arcsin\frac{x}{a} + \frac{a^2}{3}\cdot\sqrt{a^2-x^2} - \frac{a^2-x^2}{9}\cdot\sqrt{a^2-x^2} + C$$

$$= \frac{x^3}{3}\cdot arcsin\frac{x}{a} + \frac{1}{9}(x^2+2a^2)\sqrt{a^2-x^2} + C$$

116. $\int arccos\frac{x}{a}dx = x\cdot arccos\frac{x}{a} - \sqrt{a^2-x^2} + C \qquad (a>0)$

证明: $\int arccos\frac{x}{a}dx = x\cdot arccos\frac{x}{a} - \int x\,d\ arccos\frac{x}{a}$

$$= x\cdot arccos\frac{x}{a} + \int x\cdot\frac{1}{\sqrt{1-(\frac{x}{a})^2}}\cdot\frac{1}{a}dx$$

$$= x\cdot arccos\frac{x}{a} + \int\frac{x}{\sqrt{a^2-x^2}}dx$$

$$= x\cdot arccos\frac{x}{a} + \frac{1}{2}\int\frac{1}{\sqrt{a^2-x^2}}dx^2$$

$$= x\cdot arccos\frac{x}{a} - \frac{1}{2}\int(a^2-x^2)^{-\frac{1}{2}}d(a^2-x^2)$$

$$= x\cdot arccos\frac{x}{a} - \frac{1}{2}\cdot\frac{1}{1-\frac{1}{2}}\cdot(a^2-x^2)^{1-\frac{1}{2}} + C$$

$$= x\cdot arccos\frac{x}{a} - \sqrt{a^2-x^2} + C$$

117. $\int x\cdot arccos\ \frac{x}{a}dx = (\frac{x^2}{2}-\frac{a^2}{4})\cdot arccos\ \frac{x}{a} - \frac{x}{4}\sqrt{a^2-x^2} + C \qquad (a>0)$

证明: 令 $t = arccos\ \frac{x}{a}$ ，则 $x = a\cdot cos\,t$

$$\therefore \int x\cdot arccos\ \frac{x}{a}dx = \int a\cdot cos\,t\cdot t\,d(a\cdot cos\,t) = -a^2\int t\cdot cos\,t\cdot\ sin\,t\,dt$$

$$= -\frac{a^2}{2}\int t\cdot sin\,2t\,dt = \frac{a^2}{4}\int t\,d\,cos\,2t$$

$$= \frac{a^2}{4}\cdot t\cdot cos\,2t - \frac{a^2}{4}\int cos\,2t\,dt$$

$$= \frac{a^2}{4}\cdot t\cdot cos\,2t - \frac{a^2}{8}\int cos\,2t\,d2t$$

$$= \frac{a^2}{4}\cdot t\cdot cos\,2t - \frac{a^2}{8}\cdot sin\,2t + C$$

提示: $sin2x = 2\cdot sin\,x\cdot cos\,x$

$cos2x = cos^2 x - sin^2 x$

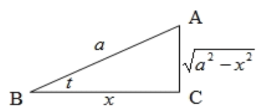
$= 2cos^2 x - 1$

$$= \frac{a^2}{4}\cdot t\cdot(2\,cos^2\,t-1) - \frac{a^2}{4}\cdot sin\,t\cdot cos\,t + C$$

$$= \frac{a^2}{2}\cdot t\cdot cos^2\,t - \frac{a^2}{4}\cdot t - \frac{a^2}{4}\cdot sin\,t\cdot cos\,t + C$$

在Rt ΔABC 中，可设 $\angle B = t$, $|AB| = a$,则 $|BC| = x$, $|AC| = \sqrt{a^2-x^2}$

$$\therefore \quad sin\,t = \frac{\sqrt{a^2-x^2}}{a}\ ,\quad cos\,t = \frac{x}{a}$$



$$\therefore \int x\cdot arccos\ \frac{x}{a}dx = \frac{a^2}{2}\cdot arcsin\ \frac{x}{a}\cdot\frac{x^2}{a^2} - \frac{a^2}{4}\cdot arcsin\ \frac{x}{a} - \frac{a^2}{4}\cdot\frac{x}{a}\cdot\frac{\sqrt{a^2-x^2}}{a} + C$$

$$= \frac{x^2}{2}\cdot arcsin\ \frac{x}{a} - \frac{a^2}{4}\cdot arcsin\ \frac{x}{a} - \frac{x}{4}\cdot\sqrt{a^2-x^2} + C$$

$$= (\frac{x^2}{2}-\frac{a^2}{4})\cdot arcsin\ \frac{x}{a} + \frac{x}{4}\sqrt{a^2-x^2} + C$$

118. $\int x^2 \cdot arccos\frac{x}{a}dx = \frac{x^3}{3}\cdot arccos\frac{x}{a} - \frac{1}{9}(x^2+2a^2)\sqrt{a^2-x^2}+C \qquad (a>0)$

证明：令$t = arccos\frac{x}{a}$，则 $x = a\cdot cost$

$$\therefore \int x^2 \cdot arccos\frac{x}{a}dx = \int a^2\cdot cos^2 t\cdot t\, d(a\cdot cost) = -a^3\int t\cdot cos^2 t\cdot sint\, dt$$

$$= \frac{a^3}{3}\int t\, d\, cos^3 t$$

$$= \frac{a^3}{3}\cdot t\cdot cos^3 t - \frac{a^3}{3}\int cos^3 t\, dt$$

$$= \frac{a^3}{3}\cdot t\cdot cos^3 t - \frac{a^3}{3}\int cost\,(1-sin^2 t)\, dt$$

$$= \frac{a^3}{3}\cdot t\cdot cos^3 t - \frac{a^3}{3}\int cost\, dt + \frac{a^3}{3}\int cost\cdot sin^2 t\, dt$$

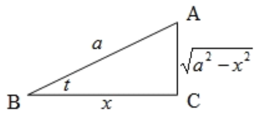
$$= \frac{a^3}{3}\cdot t\cdot cos^3 t - \frac{a^3}{3}\cdot sint + \frac{a^3}{3}\int sin^2 t\, d\, sint$$

$$= \frac{a^3}{3}\cdot t\cdot cos^3 t - \frac{a^3}{3}\cdot sint + \frac{a^3}{3}\cdot\frac{1}{1+2}\cdot sin^3 t + C$$

$$= \frac{a^3}{3}\cdot t\cdot cos^3 t - \frac{a^3}{3}\cdot sint + \frac{a^3}{9}\cdot sin^3 t + C$$

在Rt ΔABC中，可设$\angle B = t, |AB| = a$，则$|BC| = x, |AC| = \sqrt{a^2-x^2}$

$$\therefore\ sint = \frac{\sqrt{a^2-x^2}}{a},\quad cost = \frac{x}{a}$$



$$\therefore \int x^2\cdot arccos\frac{x}{a}dx = \frac{a^3}{3}\cdot arcsin\frac{x}{a}\cdot\frac{x^3}{a^3} - \frac{a^3}{3}\cdot\frac{\sqrt{a^2-x^2}}{a} + \frac{a^3}{9}\cdot\frac{a^2-x^2}{a^3}\cdot\sqrt{a^2-x^2}+C$$

$$= \frac{x^3}{3}\cdot arcsin\frac{x}{a} - \frac{a^2}{3}\cdot\sqrt{a^2-x^2} + \frac{a^2-x^2}{9}\cdot\sqrt{a^2-x^2}+C$$

$$= \frac{x^3}{3}\cdot arcsin\frac{x}{a} - \frac{1}{9}(x^2+2a^2)\sqrt{a^2-x^2}+C$$

119. $\int arctan\frac{x}{a}dx = x\cdot arctan\frac{x}{a} - \frac{a}{2}\cdot ln(a^2+x^2)+C \qquad (a>0)$

证明：$\int arctan\frac{x}{a}dx = x\cdot arctan\frac{x}{a} - \int x\, d\, x\cdot arctan\frac{x}{a}$

$$= x\cdot arctan\frac{x}{a} - \int x\cdot\frac{1}{1+(\frac{x}{a})^2}\cdot\frac{1}{a}dx$$

$$= x\cdot arctan\frac{x}{a} - a\int\frac{x}{a^2+x^2}dx$$

$$= x\cdot arctan\frac{x}{a} - \frac{a}{2}\int\frac{1}{a^2+x^2}dx^2$$

$$= x\cdot arctan\frac{x}{a} - \frac{a}{2}\int\frac{1}{a^2+x^2}d(a^2+x^2)$$

$$= x\cdot arctan\frac{x}{a} - \frac{a}{2}\cdot ln\left|\ a^2+x^2\ \right| + C$$

$\because\ a^2+x^2>0$

$$\therefore\ \int arctan\frac{x}{a}dx = x\cdot arctan\frac{x}{a} - \frac{a}{2}\cdot ln(a^2+x^2)+C$$

120. $\int x \cdot arctan\frac{x}{a}dx = \frac{1}{2}(a^2 + x^2) \cdot arctan\frac{x}{a} - \frac{a}{2} \cdot x + C \qquad (a > 0)$

证明:令$t = arctan\frac{x}{a}$，则 $x = a \cdot tan\,t$

$$\therefore \int x \cdot arctan\frac{x}{a}dx = \int a \cdot tan\,t \cdot t\,d(a \cdot tan\,t) = a^2 \int t \cdot sec^2\,t \cdot tan\,t\,dt$$

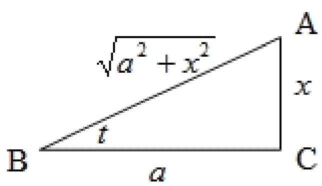
$$= \frac{a^2}{2}\int t\,d\,sec^2\,t$$

$$= \frac{a^2}{2} \cdot t \cdot sec^2\,t - \frac{a^2}{2}\int sec^2\,t\,dt$$

$$= \frac{a^2}{2} \cdot t \cdot sec^2\,t - \frac{a^2}{2} \cdot tan\,t + C$$

在Rt $\varDelta ABC$中，可设$\angle B = t$,$|BC| = a$,则$|AC| = x$,$|AB| = \sqrt{a^2 + x^2}$

$$\therefore\ sec\,t = \frac{1}{cos\,t} = \frac{\sqrt{a^2 + x^2}}{a}\ ,\ tan\,t = \frac{x}{a}$$



$$\therefore \int x \cdot arctan\frac{x}{a}dx = \frac{a^2}{2} \cdot arctan\frac{x}{a} \cdot \frac{a^2 + x^2}{a^2} - \frac{a^2}{2} \cdot \frac{x}{a} + C$$

$$= \frac{1}{2}(a^2 + x^2) \cdot arctan\frac{x}{a} - \frac{a}{2} \cdot x + C$$

121. $\int x^2 \cdot arctan\frac{x}{a}dx = \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{6} \cdot x^2 + \frac{a^3}{6}ln(a^2 + x^2) + C \qquad (a > 0)$

证明: $\therefore \int x^2 \cdot arctan\frac{x}{a}dx = \frac{1}{3}\int arctan\frac{x}{a}dx^3$

$$= \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{1}{3}\int x^3 \cdot \frac{1}{1 + (\frac{x}{a})^2} \cdot \frac{1}{a}dx$$

$$= \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{3}\int \frac{x^3}{a^2 + x^2}dx$$

$$= \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{6}\int \frac{x^2}{a^2 + x^2}dx^2$$

$$= \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{6}\int \frac{x^2 + a^2 - a^2}{a^2 + x^2}dx^2$$

$$= \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{6}\int dx^2 + \frac{a}{6}\int \frac{a^2}{a^2 + x^2}dx^2$$

$$= \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{6}\int dx^2 + \frac{a^3}{6}\int \frac{1}{a^2 + x^2}d(x^2 + a^2)$$

$$= \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{6} \cdot x^2 + \frac{a^3}{6}ln\left| a^2 + x^2 \right| + C$$

$\because\ a^2 + x^2 > 0$

$$\therefore \int x^2 \cdot arctan\frac{x}{a}dx = \frac{x^3}{3} \cdot arctan\frac{x}{a} - \frac{a}{6} \cdot x^2 + \frac{a^3}{6}ln(a^2 + x^2) + C$$

（十三）含有指数函数的积分（122~131）

122. $\int a^x dx = \frac{1}{ln a} \cdot a^x + C$

证明：$\int a^x dx = \frac{1}{ln a}\int ln a \cdot a^x dx$

$\because (a^x)' = a^x\, ln a$，即$a^x\, ln a$的原函数为$a^x$

$\therefore \int a^x dx = \frac{1}{ln a}\int da^x$

$= \frac{1}{ln a} \cdot a^x + C$

123. $\int e^{ax} dx = \frac{1}{a} \cdot e^{ax} + C$

证明：令 $ax = \mu$，则 $x = \frac{\mu}{a}$，$dx = \frac{1}{a} d\mu$

$\therefore \int e^{ax} dx = \frac{1}{a}\int e^{\mu} d\mu = \frac{1}{a} \cdot e^{\mu} + C$

$= \frac{1}{a} \cdot e^{ax} + C$

124. $\int x \cdot e^{ax} dx = \frac{1}{a^2}(ax-1)e^{ax} + C$

证明：$\int x \cdot e^{ax} dx = \frac{1}{a}\int x\, de^{ax}$

$= \frac{1}{a} \cdot x \cdot e^{ax} - \frac{1}{a}\int e^{ax} dx$

$= \frac{1}{a} \cdot x \cdot e^{ax} - \frac{1}{a^2}\int e^{ax} dax$

$= \frac{1}{a} \cdot x \cdot e^{ax} - \frac{1}{a^2} e^{ax} + C$

$= \frac{1}{a^2}(ax-1)e^{ax} + C$

125. $\int x^n \cdot e^{ax} dx = \frac{1}{a} \cdot x^n \cdot e^{ax} - \frac{n}{a}\int x^{n-1} \cdot e^{ax} dx$

证明：$\int x^n \cdot e^{ax} dx = \frac{1}{a}\int x^n\, de^{ax}$

$= \frac{1}{a} \cdot x^n \cdot e^{ax} - \frac{1}{a}\int e^{ax} dx^n$

$= \frac{1}{a} \cdot x^n \cdot e^{ax} - \frac{n}{a}\int x^{n-1} \cdot e^{ax} dx$

126. $\int x\cdot a^x dx=\frac{x}{ln\,a}\cdot a^x-\frac{1}{(ln\,a)^2}\cdot a^x+C$

证明：$\int x\cdot a^x dx=\frac{1}{ln\,a}\int x\,da^x$

$=\frac{1}{ln\,a}\cdot x\cdot a^x-\frac{1}{ln\,a}\int a^x dx$ 　　公式122：$\int a^x dx=\frac{1}{ln\,a}\cdot a^x+C$

$=\frac{1}{ln\,a}\cdot x\cdot a^x-\frac{1}{(ln\,a)^2}\cdot a^x+C$

127. $\int x^n\cdot a^x dx=\frac{1}{ln\,a}\cdot x^n\cdot a^x-\frac{n}{ln\,a}\int x^{n-1}\cdot a^x dx$

证明：$\int x^n\cdot a^x dx=\frac{1}{ln\,a}\int x^n\,da^x$

$=\frac{1}{ln\,a}\cdot x^n\cdot a^x-\frac{1}{ln\,a}\int a^x dx^n$

$=\frac{1}{ln\,a}\cdot x^n\cdot a^x-\frac{n}{ln\,a}\int x^{n-1}\cdot a^x dx$

128. $\int e^{ax}\cdot sin\,bx\,dx=\frac{1}{a^2+b^2}\cdot e^{ax}(a\cdot sin\,bx-b\cdot cos\,bx)+C$

证明：$\int e^{ax}\cdot sin\,bx\,dx=-\frac{1}{b}\int e^{ax}d\,cos\,bx$

$=-\frac{1}{b}\cdot e^{ax}\cdot cos\,bx+\frac{1}{b}\int cos\,bxde^{ax}$

$=-\frac{1}{b}\cdot e^{ax}\cdot cos\,bx+\frac{a}{b^2}\cdot e^{ax}\cdot sin\,bx-\frac{a}{b^2}\int sin\,bx\,de^{ax}$

$=-\frac{1}{b}\cdot e^{ax}\cdot cos\,bx+\frac{a}{b^2}\cdot e^{ax}\cdot sin\,bx-\frac{a}{b^2}\int sin\,bx\,de^{ax}$

移项并整理得：$\frac{a^2+b^2}{b^2}\int e^{ax}\cdot sin\,bx\,dx=-\frac{1}{b}\cdot e^{ax}\cdot cos\,bx+\frac{a}{b^2}\cdot e^{ax}\cdot sin\,bx+C$

$\therefore\int e^{ax}\cdot sin\,bx\,dx=-\frac{b}{a^2+b^2}\cdot e^{ax}\cdot cos\,bx+\frac{a}{a^2+b^2}\cdot e^{ax}\cdot sin\,bx+C$

$=\frac{1}{a^2+b^2}\cdot e^{ax}(a\cdot sin\,bx-b\cdot cos\,bx)+C$

129. $\int e^{ax}\cdot \cos bx dx=\frac{1}{a^2+b^2}\cdot e^{ax}(b\cdot \sin bx+a\cdot \cos bx)+C$

证明：$\int e^{ax}\cdot \cos bx dx=\frac{1}{b}\int e^{ax} d\sin bx$

$$=\frac{1}{b}\cdot e^{ax}\cdot \sin bx-\frac{1}{b}\int \sin bx de^{ax}$$

$$=\frac{1}{b}\cdot e^{ax}\cdot \sin bx-\frac{a}{b}\int \sin bx\cdot e^{ax}dx$$

$$=\frac{1}{b}\cdot e^{ax}\cdot \sin bx+\frac{a}{b^2}\int e^{ax} d\cos bx$$

$$=\frac{1}{b}\cdot e^{ax}\cdot \sin bx+\frac{a}{b^2}\cdot e^{ax}\cdot \cos bx-\frac{a}{b^2}\int \cos bx de^{ax}$$

$$=\frac{1}{b}\cdot e^{ax}\cdot \sin bx+\frac{a}{b^2}\cdot e^{ax}\cdot \cos bx-\frac{a^2}{b^2}\int e^{ax}\cdot \cos bx dx$$

$\therefore\ (1+\frac{a^2}{b^2})\int e^{ax}\cdot \cos bx dx=\frac{a^2+b^2}{b^2}\int e^{ax}\cdot \cos bx dx=\frac{1}{b}\cdot e^{ax}\cdot \sin bx+\frac{a}{b^2}\cdot e^{ax}\cdot \cos bx$

$\therefore\ \int e^{ax}\cdot \cos bx dx=\frac{1}{a^2+b^2}\cdot e^{ax}(b\cdot \sin bx+a\cdot \cos bx)+C$

130. $\int e^{ax}\cdot sin^n bx\,dx=\frac{1}{a^2+b^2n^2}\cdot e^{ax}\cdot sin^{n-1}bx(a\cdot sin bx-nb\cdot cos bx)$

$$+\frac{n\cdot(n-1)b^2}{a^2+b^2n^2}\int e^{ax}\cdot sin^{n-2}bx\,dx$$

证明:$\int e^{ax}\cdot sin^n bx\,dx=\int e^{ax}\cdot sin^{n-2}bx\cdot sin^2 bx\,dx=\int e^{ax}\cdot sin^{n-2}bx\cdot(1-cos^2 bx)\,dx$

$$=\int e^{ax}\cdot sin^{n-2}bx\,dx-\int e^{ax}\cdot sin^{n-2}bx\cdot cos^2 bx\,dx \quad ①$$

又 $\int e^{ax}\cdot sin^{n-2}bx\cdot cos^2 bx\,dx=\frac{1}{b\cdot(n-1)}\int e^{ax}\cdot cos bx\,d\,sin^{n-1}bx$

$$=\frac{1}{b\cdot(n-1)}\cdot e^{ax}\cdot cos bx\cdot sin^{n-1}bx-\frac{1}{b\cdot(n-1)}\int sin^{n-1}bx\,d(e^{ax}\cdot cos bx) \quad ②$$

又 $\int sin^{n-1}bx\,d(e^{ax}\cdot cos bx)=\int sin^{n-1}bx(a\cdot e^{ax}\cdot cos bx-b\cdot sin bx\cdot e^{ax})dx$

$$=a\int e^{ax}\cdot sin^{n-1}bx\cdot cos bx\,dx-b\int sin^n bx\cdot e^{ax}dx \quad ③$$

又 $\int e^{ax}\cdot sin^{n-1}bx\cdot cos bx\,dx=\frac{1}{b}\int e^{ax}\cdot sin^{n-1}bx\,d\,sin bx$

$$=\frac{1}{b}\cdot e^{ax}\cdot sin^n bx-\frac{1}{b}\int sin bx\,d(e^{ax}\cdot sin^{n-1}bx)$$

$$=\frac{1}{b}\cdot e^{ax}\cdot sin^n bx-\frac{1}{b}\int sin bx[a\cdot e^{ax}\cdot sin^{n-1}bx+b\cdot(n-1)sin^{n-2}bx\cdot cos bx\cdot e^{ax}]dx$$

$$=\frac{1}{b}\cdot e^{ax}\cdot sin^n bx-\frac{a}{b}\int sin^n bx\cdot e^{ax}dx-(n-1)\int e^{ax}\cdot sin^{n-1}bx\cdot cos bx\,dx$$

移项并整理得:$\int e^{ax}\cdot sin^{n-1}bx\cdot cos bx\,dx=\frac{1}{bn}\cdot e^{ax}\cdot sin^n bx-\frac{a}{bn}\int sin^n bx\cdot e^{ax}dx$ ④

将④式代入③式的得:$\int sin^{n-1}bx\,d(e^{ax}\cdot cos bx)$

$$=\frac{a}{bn}\cdot e^{ax}\cdot sin^n bx-\frac{a^2}{bn}\int sin^n bx\cdot e^{ax}dx-b\int sin^n bx\cdot e^{ax}dx$$

$$=\frac{a}{bn}\cdot e^{ax}\cdot sin^n bx-\frac{a^2+b^2n}{bn}\int sin^n bx\cdot e^{ax}dx \quad ⑤$$

将⑤式代入②式得:$\int e^{ax}\cdot sin^{n-2}bx\cdot cos^2 bx\,dx=\frac{1}{b\cdot(n-1)}\cdot e^{ax}\cdot cos bx\cdot sin^{n-1}bx$

$$-\frac{a}{b^2\cdot n\cdot(n-1)}\cdot e^{ax}\cdot sin^n bx+\frac{a^2+b^2n}{b^2\cdot n\cdot(n-1)}\int sin^n bx\cdot e^{ax}dx$$

将 式代入①式得:$\int e^{ax}\cdot sin^n bx\,dx=\int e^{ax}\cdot sin^{n-2}bx\,dx-\frac{1}{b\cdot(n-1)}\cdot e^{ax}\cdot cos bx\cdot sin^{n-1}bx$

$$+\frac{a}{b^2\cdot n\cdot(n-1)}\cdot e^{ax}\cdot sin^n bx-\frac{a^2+b^2n}{b^2\cdot n\cdot(n-1)}\int sin^n bx\cdot e^{ax}dx$$

移项并整理得:$\int e^{ax}\cdot sin^n bx\,dx$

$$=\frac{n\cdot(n-1)b^2}{a^2+b^2n^2}\left[\int e^{ax}\cdot sin^{n-2}bx\,dx-\frac{1}{b\cdot(n-1)}\cdot e^{ax}\cdot cos bx\cdot sin^{n-1}bx+\frac{1}{n\cdot(n-1)b^2}\cdot e^{ax}\cdot sin^n bx\right]$$

$$=\frac{n\cdot(n-1)b^2}{a^2+b^2n^2}\cdot\int e^{ax}\cdot sin^{n-2}bx\,dx-\frac{bn}{a^2+b^2n^2}\cdot e^{ax}\cdot cos bx\cdot sin^{n-1}bx+\frac{a}{a^2+b^2n^2}\cdot e^{ax}\cdot sin^n bx$$

$$=\frac{1}{a^2+b^2n^2}\cdot e^{ax}\cdot sin^{n-1}bx(a\cdot sin bx-nb\cdot cos bx)$$

$$+\frac{n\cdot(n-1)b^2}{a^2+b^2n^2}\int e^{ax}\cdot sin^{n-2}bx\,dx$$

131. $\int e^{ax}\cdot cos^n bx\,dx=\frac{1}{a^2+b^2n^2}\cdot e^{ax}\cdot cos^{n-1}bx(a\cdot cos\,bx+nb\cdot sin\,bx)$

$$+\frac{n\cdot(n-1)b^2}{a^2+b^2n^2}\int e^{ax}\cdot cos^{n-2}bx\,dx$$

证明：$\int e^{ax}\cdot cos^n bx\,dx=\int e^{ax}\cdot cos^{n-2}bx\cdot cos^2 bx\,dx=\int e^{ax}\cdot cos^{n-2}bx\cdot(1-sin^2 bx)\,dx$

$$=\int e^{ax}\cdot cos^{n-2}bx\,dx-\int e^{ax}\cdot cos^{n-2}bx\cdot sin^2 bx\,dx \qquad ①$$

又 $\int e^{ax}\cdot cos^{n-2}bx\cdot sin^2 bx\,dx=\frac{1}{b\cdot(1-n)}\int e^{ax}\cdot sin\,bx\,d\,cos^{n-1}bx$

$$=\frac{1}{b\cdot(1-n)}\cdot e^{ax}\cdot sin\,bx\cdot cos^{n-1}bx-\frac{1}{b\cdot(1-n)}\int cos^{n-1}bx\,d(e^{ax}\cdot sin\,bx) \qquad ②$$

又 $\int cos^{n-1}bx\,d(e^{ax}\cdot sin\,bx)=\int cos^{n-1}bx\,(a\cdot e^{ax}\cdot sin\,bx+b\cdot cos\,bx\cdot e^{ax})dx$

$$=a\int e^{ax}\cdot cos^{n-1}bx\cdot sin\,bx\,dx+b\int cos^n bx\cdot e^{ax}dx \qquad ③$$

又 $\int e^{ax}\cdot cos^{n-1}bx\cdot sin\,bx\,dx=-\frac{1}{b}\int e^{ax}\cdot cos^{n-1}bx\,d\,cos\,bx$

$$=-\frac{1}{b}\cdot e^{ax}\cdot cos^n bx+\frac{1}{b}\int cos\,bx\,d(e^{ax}\cdot cos^{n-1}bx)$$

$$=-\frac{1}{b}\cdot e^{ax}\cdot cos^n bx+\frac{1}{b}\int cos\,bx[a\cdot e^{ax}\cdot cos^{n-1}bx-b\cdot(n-1)cos^{n-2}bx\cdot sin\,bx\cdot e^{ax}]dx$$

$$=-\frac{1}{b}\cdot e^{ax}\cdot cos^n bx+\frac{a}{b}\int cos^n bx\cdot e^{ax}dx-(n-1)\int e^{ax}\cdot cos^{n-1}bx\cdot sin\,bx\,dx$$

移项并整理得：$\int e^{ax}\cdot cos^{n-1}bx\cdot sin\,bx\,dx=-\frac{1}{bn}\cdot e^{ax}\cdot cos^n bx+\frac{a}{bn}\int cos^n bx\cdot e^{ax}dx \qquad ④$

将④式代入③式的得：$\int cos^{n-1}bx\,d(e^{ax}\cdot sin\,bx)$

$$=-\frac{a}{bn}\cdot e^{ax}\cdot cos^n bx+\frac{a^2}{bn}\int cos^n bx\cdot e^{ax}dx+b\int cos^n bx\cdot e^{ax}dx$$

$$=-\frac{a}{bn}\cdot e^{ax}\cdot cos^n bx+\frac{a^2+b^2n}{bn}\int cos^n bx\cdot e^{ax}dx \qquad ⑤$$

将⑤式代入②式得：$\int e^{ax}\cdot cos^{n-2}bx\cdot sin^2 bx\,dx=\frac{1}{b\cdot(1-n)}\cdot e^{ax}\cdot sin\,bx\cdot cos^{n-1}bx$

$$+\frac{a}{b^2\cdot n\cdot(1-n)}\cdot e^{ax}\cdot cos^n bx-\frac{a^2+b^2n}{b^2\cdot n\cdot(1-n)}\int cos^n bx\cdot e^{ax}dx$$

将　式代入①式得：$\int e^{ax}\cdot cos^n bx\,dx=\int e^{ax}\cdot cos^{n-2}bx\,dx-\frac{1}{b\cdot(1-n)}\cdot e^{ax}\cdot sin\,bx\cdot cos^{n-1}bx$

$$+\frac{a}{b^2\cdot n\cdot(n-1)}\cdot e^{ax}\cdot cos^n bx-\frac{a^2+b^2n}{b^2\cdot n\cdot(n-1)}\int cos^n bx\cdot e^{ax}dx$$

移项并整理得：$\int e^{ax}\cdot cos^n bx\,dx$

$$=\frac{n\cdot(1-n)b^2}{-a^2-b^2n^2}\left[\int e^{ax}\cdot cos^{n-2}bx\,dx-\frac{1}{b\cdot(1-n)}\cdot e^{ax}\cdot sin\,bx\cdot cos^{n-1}bx-\frac{a}{n\cdot(1-n)b^2}\cdot e^{ax}\cdot cos^n bx\right]$$

$$=\frac{n\cdot(n-1)b^2}{a^2+b^2n^2}\cdot\int e^{ax}\cdot cos^{n-2}bx\,dx+\frac{bn}{a^2+b^2n^2}\cdot e^{ax}\cdot sin\,bx\cdot cos^{n-1}bx+\frac{a}{a^2+b^2n^2}\cdot e^{ax}\cdot cos^n bx$$

$$=\frac{1}{a^2+b^2n^2}\cdot e^{ax}\cdot cos^{n-1}bx(a\cdot cos\,bx+nb\cdot sin\,bx)+\frac{n\cdot(n-1)b^2}{a^2+b^2n^2}\int e^{ax}\cdot cos^{n-2}bx\,dx$$

（十四）含有对数函数的积分（132~136）

132. $\int ln\, x dx = x \cdot ln\, x - x + C$

证明：$\int ln\, x dx = x \cdot ln\, x - \int x\, d\, ln\, x$

$$= x \cdot ln\, x - \int x \cdot \frac{1}{x}\, dx$$

$$= x \cdot ln\, x - \int dx$$

$$= x \cdot ln\, x - x + C$$

133. $\int \frac{dx}{x \cdot ln\, x} dx = ln\left| ln\, x \right| + C$

证明：$\int \frac{dx}{x \cdot ln\, x} dx = \int \frac{1}{ln\, x} d\, ln\, x$

$$= ln\left| ln\, x \right| + C$$

提示：$(ln\, x)' = \frac{1}{x}$

134. $\int x^n \cdot ln\, x\, dx = \frac{1}{n+1} \cdot x^{n+1}(ln\, x - \frac{1}{n+1}) + C$

证明：$\int x^n \cdot ln\, x\, dx = \int \frac{ln\, x}{n+1} \cdot (n+1) \cdot x^n dx$

$$= \int \frac{ln\, x}{n+1}\, dx^{n+1}$$

$$= \frac{ln\, x}{n+1} \cdot x^{n+1} - \frac{1}{n+1} \int x^{n+1} d\, ln\, x$$

$$= \frac{ln\, x}{n+1} \cdot x^{n+1} - \frac{1}{n+1} \int x^n dx$$

$$= \frac{ln\, x}{n+1} \cdot x^{n+1} - (\frac{1}{n+1})^2 \cdot x^{n+1} + C$$

$$= \frac{1}{n+1} \cdot x^{n+1}(ln\, x - \frac{1}{n+1}) + C$$

135. $\int (lnx)^n dx = x\cdot(lnx)^n - n\int (lnx)^{n-1}dx$

$$= x\sum_{k=0}^{n}(-1)^{n-k}\cdot\frac{n!}{k!}\cdot(lnx)^k$$

证明：$\int (lnx)^n dx = x\cdot(lnx)^n - \int xd(lnx)^n$

$$= x\cdot(lnx)^n - \int x\cdot n\cdot(lnx)^{n-1}\cdot\frac{1}{x}dx$$

$$= x\cdot(lnx)^n - n\int (lnx)^{n-1}dx$$

$$= x\cdot(lnx)^n - n\cdot x\cdot(lnx)^{n-1} + n\int xd(lnx)^{n-1}$$

$$= x\cdot(lnx)^n - n\cdot x\cdot(lnx)^{n-1} + n\cdot(n-1)\int (lnx)^{n-2}dx$$

$$= x\cdot(lnx)^n - n\cdot x\cdot(lnx)^{n-1} + n\cdot(n-1)\cdot x\cdot(lnx)^{n-2} - n\cdot(n-1)\cdot(n-2)\int (lnx)^{n-3}dx$$

....

$$= x\cdot(lnx)^n - n\cdot x\cdot(lnx)^{n-1} + n\cdot(n-1)\cdot x\cdot(lnx)^{n-2} - n\cdot(n-1)\cdot(n-2)(lnx)^{n-3}$$

$$+\cdots\cdots+(-1)^{n-k}\cdot n\cdot(n-1)\cdot(n-2)\cdots\cdots(n-k+1)\cdot(lnx)^{n-k}+\cdots\cdots$$

$$+(-1)^2\cdot n\cdot(n-1)\cdot(n-2)\cdots\cdots 5\times4\times3\cdot(lnx)^{3-1}\cdot x$$

$$+(-1)^1\cdot n\cdot(n-1)\cdot(n-2)\cdots\cdots 4\times3\times2\cdot(lnx)^{2-1}\cdot x$$

$$+(-1)^0\cdot n\cdot(n-1)\cdot(n-2)\cdots\cdots 3\times2\times1\cdot(lnx)^{1-1}\cdot x$$

$$= x\sum_{k=0}^{n}(-1)^{n-k}\cdot\frac{n!}{k!}\cdot(lnx)^k$$

136. $\int x^m\cdot(ln\,x)^{\mathrm{n}}\,dx = \frac{1}{m+1}\cdot x^{m+1}\cdot(ln\,x)^{\mathrm{n}} - \frac{\mathrm{n}}{m+1}\int x^m\cdot(ln\,x)^{\mathrm{n}-1}\,dx$

证明：$\int x^m\cdot(ln\,x)^{\mathrm{n}}\,dx = \frac{1}{m+1}\int (ln\,x)^{\mathrm{n}}dx^{m+1}$

$$= \frac{1}{m+1}\cdot x^{m+1}\cdot(ln\,x)^{\mathrm{n}} - \frac{1}{m+1}\int x^{m+1}\,d(ln\,x)^{\mathrm{n}}$$

$$= \frac{1}{m+1}\cdot x^{m+1}\cdot(ln\,x)^{\mathrm{n}} - \frac{\mathrm{n}}{m+1}\int x^{m+1}\cdot(ln\,x)^{\mathrm{n}-1}\cdot\frac{1}{x}dx$$

$$= \frac{1}{m+1}\cdot x^{m+1}\cdot(ln\,x)^{\mathrm{n}} - \frac{\mathrm{n}}{m+1}\int x^m\cdot(ln\,x)^{\mathrm{n}-1}\,dx$$

（十五）含有双曲函数的积分（137~141）

137. $\int shx\,dx = chx + C$

证明：$\because (chx)' = shx$,即chx为shx的原函数

$\therefore \int shx\,dx = \int d\,chx$

$= chx + C$

138. $\int ch\,x\,dx = shx + C$

证明：$\because (shx)' = chx$,即shx为chx的原函数

$\therefore \int ch\,x\,dx = \int d\,shx$

$= shx + C$

139. $\int th\,x\,dx = ln\,chx + C$

证明:$\int th\,x\,dx = \int \frac{shx}{chx}dx$

$= \int \frac{1}{chx}d\,chx$

$= ln\,chx + C$

140. $\int sh^2 x\,dx = -\frac{x}{2} + \frac{1}{4}sh\,2x + C$

证明:$\int sh^2 x\,dx = \int \left(\frac{e^x - e^{-x}}{2}\right)^2 dx$

$= \frac{1}{4}\int (e^{2x} + e^{-2x} - 2)dx$

$= \frac{e^{2x}}{8} - \frac{e^{-2x}}{8} - \frac{x}{2} + C$

$= -\frac{x}{2} + \frac{1}{4}\cdot\frac{e^{2x} - e^{-2x}}{2} + C$

$= -\frac{x}{2} + \frac{1}{4}\cdot sh\,2x + C$

> 提示：$chx = \frac{e^x + e^{-x}}{2}$ (双曲余弦)
>
> $shx = \frac{e^x - e^{-x}}{2}$ (双曲余弦)

141. $\int ch^2 x\,dx = \frac{x}{2} + \frac{1}{4}\cdot sh\,2x + C$

证明:$\int ch^2 x\,dx = \int \left(\frac{e^x + e^{-x}}{2}\right)^2 dx$

$= \frac{1}{4}\int (e^{2x} + e^{-2x} + 2)dx$

$= \frac{e^{2x}}{8} - \frac{e^{-2x}}{8} + \frac{x}{2} + C$

$= \frac{x}{2} + \frac{1}{4}\cdot\frac{e^{2x} - e^{-2x}}{2} + C$

$= \frac{x}{2} + \frac{1}{4}\cdot sh\,2x + C$

> 提示：$chx = \frac{e^x + e^{-x}}{2}$ (双曲余弦)
>
> $shx = \frac{e^x - e^{-x}}{2}$ (双曲余弦)

（十六）定积分（142~147）

142. $\int_{-\pi}^{\pi} cos\, nx\, dx = \int_{-\pi}^{\pi} sin\, nx\, dx = 0$

证明①：$\int_{-\pi}^{\pi} cos\, nx\, dx = \frac{1}{n}\int_{-\pi}^{\pi} cos\, nx\, dnx$

$$= \frac{1}{n}\cdot (sin\, nx\Big|_{-\pi}^{\pi})$$

$$= \frac{1}{n}\cdot sin\,(n\pi) - \frac{1}{n}\cdot sin\,(-n\pi)$$

$$= \frac{2}{n}\cdot sin\,(n\pi)$$

$$= 0$$

证明②：$\int_{-\pi}^{\pi} sin\, nx\, dx = \frac{1}{n}\int_{-\pi}^{\pi} sin\, nx\, dnx$

$$= -\frac{1}{n}\cdot (cos\, nx\Big|_{-\pi}^{\pi})$$

$$= -\frac{1}{n}\cdot cos\,(n\pi) + \frac{1}{n}\cdot cos\,(-n\pi)$$

$$= 0$$

综合证明①②得：$\int_{-\pi}^{\pi} cos\, nx\, dx = \int_{-\pi}^{\pi} sin\, nx\, dx = 0$

143. $\int_{-\pi}^{\pi} cos\, mx\cdot sin\, nx\, dx = 0$

公式 100 ：$\int sin\, ax\cdot cos\, bx\, dx = -\frac{1}{2(a+b)}\cdot cos\,(a+b)x - \frac{1}{2(a-b)}\cdot cos\,(a-b)x + C$

证明：1.当 $m \neq n$ 时

$$\int_{-\pi}^{\pi} cos\, mx\cdot sin\, nx\, dx = -\frac{1}{2(m+n)}\cdot cos(m+n)x\Big|_{-\pi}^{\pi} - \frac{1}{2(n-m)} cos(n-m)x\Big|_{-\pi}^{\pi}$$

$$= -\frac{1}{2(m+n)}[cos(m+n)\pi - cos(m+n)\pi] - \frac{1}{2(n-m)}[cos(n-m)\pi - cos(n-m)(-\pi)]$$

$$= 0 + 0 = 0$$

2.当 $m = n$ 时

$$\int_{-\pi}^{\pi} cos\, mx\cdot sin\, nx\, dx = \int_{-\pi}^{\pi} cos\, mx\cdot sin\, mx\, dx$$

提示：$sin 2x = 2\cdot sin\, x\cdot cos\, x$

$$= \frac{1}{2m}\int_{-\pi}^{\pi} sin\, 2mx\, d\, mx$$

$$= \frac{1}{4m}\int_{-\pi}^{\pi} sin\, 2mx\, d\, 2mx$$

$$= -\frac{1}{4m}\cdot cos 2mx\Big|_{-\pi}^{\pi}$$

$$= -\frac{1}{4m}\cdot [cos 2m\pi - cos(-2m\pi)]$$

$$= 0$$

综合讨论1, 2 得：$\int_{-\pi}^{\pi} cos\, nx\, dx = \int_{-\pi}^{\pi} cos\, mx\cdot sin\, nx\, dx = 0$

144. $\int_{-\pi}^{\pi} \cos mx \cdot \cos nx\, dx = \begin{cases} 0, & m \neq n \\ \pi, & m = n \end{cases}$

证明：1.当$m \neq n$时

$$\int_{-\pi}^{\pi} \cos mx \cdot \cos nx\, dx = \frac{1}{2(m+n)} \cdot \sin(m+n)x \Big|_{-\pi}^{\pi} - \frac{1}{2(m-n)} \sin(m-n)x \Big|_{-\pi}^{\pi}$$

$$= \frac{1}{2(m+n)}[\sin(m+n)\pi - \sin(m+n)(-\pi)] - \frac{1}{2(m-n)}[\sin(m-n)\pi + \sin(m-n)(-\pi)]$$

$$= 0 - 0 = 0$$

> 公式102：$\int \cos ax \cdot \cos bx\, dx = \frac{1}{2(a+b)} \cdot \sin(a+b)x + \frac{1}{2(a-b)} \cdot \sin(a-b)x + C$

2.当$m = n$时

$$\int_{-\pi}^{\pi} \cos mx \cdot \cos nx\, dx = \int_{-\pi}^{\pi} \cos mx \cdot \cos mx\, dx$$

$$= \frac{1}{m} \int_{-\pi}^{\pi} \cos^2 mx\, d\, mx$$

> 公式 94：$\int \cos^2 x\, dx = \frac{x}{2} + \frac{1}{4} \cdot \sin 2x + C$

$$= \frac{1}{4m} \cdot \sin 2mx \Big|_{-\pi}^{\pi} + \frac{1}{2m} \cdot mx \Big|_{-\pi}^{\pi}$$

$$= \frac{1}{4m} \cdot [\sin 2m\pi - \sin(-2m\pi)] + \frac{\pi}{2} + \frac{\pi}{2}$$

$$= \pi$$

综合讨论1，2得：$\int_{-\pi}^{\pi} \cos mx \cdot \cos nx\, dx = \begin{cases} 0, & m \neq n \\ \pi, & m = n \end{cases}$

145. $\int_{-\pi}^{\pi} \sin mx \cdot \sin nx\, dx = \begin{cases} 0, & m \neq n \\ \pi, & m = n \end{cases}$

证明：1.当$m \neq n$时

$$\int_{-\pi}^{\pi} \sin mx \cdot \sin nx\, dx = -\frac{1}{2(m+n)} \cdot \sin(m+n)x \Big|_{-\pi}^{\pi} + \frac{1}{2(m-n)} \sin(m-n)x \Big|_{-\pi}^{\pi}$$

$$= -\frac{1}{2(m+n)}[\sin(m+n)\pi - \sin(m+n)(-\pi)] + \frac{1}{2(m-n)}[\sin(m-n)\pi - \sin(m-n)(-\pi)]$$

$$= 0 + 0 = 0$$

> 公式101：$\int \sin ax \cdot \sin bx\, dx = -\frac{1}{2(a+b)} \cdot \sin(a+b)x + \frac{1}{2(a-b)} \cdot \sin(a-b)x + C$

2.当$m = n$时

$$\int_{-\pi}^{\pi} \sin mx \cdot \sin nx\, dx = \int_{-\pi}^{\pi} \sin^2 mx\, dx$$

> 公式 93：$\int \sin^2 x\, dx = \frac{x}{2} - \frac{1}{4} \cdot \sin 2x + C$

$$= \frac{1}{m} \int_{-\pi}^{\pi} \sin^2 mx\, d\, mx$$

$$= \frac{1}{2m} \cdot mx \Big|_{-\pi}^{\pi} - \frac{1}{4m} \cdot \sin 2mx \Big|_{-\pi}^{\pi}$$

$$= -\frac{1}{4m} \cdot [\sin 2m\pi - \sin(-2m\pi)] + \frac{\pi}{2} + \frac{\pi}{2}$$

$$= \pi$$

综合讨论1，2得：$\int_{-\pi}^{\pi} \sin mx \cdot \sin nx\, dx = \begin{cases} 0, & m \neq n \\ \pi, & m = n \end{cases}$

146. $\int_0^{\pi} sin\,mx\cdot sin\,nx\,dx=\int_0^{\pi} cos\,mx\cdot cos\,nx\,dx\begin{cases}0,\ m\neq n\\ \frac{\pi}{2},\ m=n\end{cases}$

证明：1.当$m\neq n$时

$$\int_0^{\pi} sin\,mx\cdot sin\,nx\,dx=-\frac{1}{2(m+n)}\cdot sin\,(m+n)x\Big|_0^{\pi}+\frac{1}{2(m-n)}sin\,(m-n)x\Big|_0^{\pi}$$

$$=-\frac{1}{2(m+n)}[sin\,(m+n)\pi-sin\,0]+\frac{1}{2(m-n)}[sin\,(m-n)\pi-sin\,0]$$

$$=0+0=0$$

$$\int_0^{\pi} cos\,mx\cdot cos\,nx\,dx=\frac{1}{2(m+n)}\cdot sin\,(m+n)x\Big|_0^{\pi}+\frac{1}{2(m-n)}sin\,(m-n)x\Big|_0^{\pi}$$

$$=\frac{1}{2(m+n)}[sin\,(m+n)\pi-sin\,0]+\frac{1}{2(m-n)}[sin\,(m-n)\pi+sin\,0]$$

$$=0+0=0$$

2.当$m=n$时

$$\int_0^{\pi} sin\,mx\cdot sin\,nx\,dx=\int_0^{\pi} sin^2\ mx\,dx$$

$$=\frac{1}{m}\int_0^{\pi} sin^2\ mx\,d\,mx$$

$$=\frac{1}{2m}\cdot mx\Big|_0^{\pi}-\frac{1}{4m}\cdot sin\,2mx\Big|_0^{\pi}$$

$$=-\frac{1}{4m}\cdot[sin\,2m\pi-sin\,0]+\frac{\pi}{2}+0$$

$$=\frac{\pi}{2}$$

$$\int_0^{\pi} cos\,mx\cdot cos\,nx\,dx=\int_0^{\pi} cos\,mx\cdot cos\,mx\,dx$$

$$=\frac{1}{m}\int_0^{\pi} cos^2\ mx\,d\,mx$$

$$=\frac{1}{4m}\cdot sin\,2mx\Big|_0^{\pi}+\frac{1}{2m}\cdot mx\Big|_0^{\pi}$$

$$=\frac{1}{4m}\cdot[sin\,2m\pi-sin\,0]+\frac{\pi}{2}+0$$

$$=\frac{\pi}{2}$$

综合讨论1,2得：$\int_0^{\pi} sin\,mx\cdot sin\,nx\,dx=\int_0^{\pi} cos\,mx\cdot cos\,nx\,dx\begin{cases}0,\ m\neq n\\ \frac{\pi}{2},\ m=n\end{cases}$

以上所用公式：

公式 101：$\int sin\ ax\cdot sin\ bx\ dx=-\frac{1}{2(a+b)}\cdot sin\ (a+b)x+\frac{1}{2(a-b)}\cdot sin\ (a-b)x+C$

公式 102：$\int cos\ ax\cdot cos\ bx\ dx=\frac{1}{2(a+b)}\cdot sin\ (a+b)x+\frac{1}{2(a-b)}\cdot sin\ (a-b)x+C$

公式 93：$\int sin^2 x\ dx=\frac{x}{2}-\frac{1}{4}\cdot sin\ 2x+C$

公式 94：$\int cos^2\ x\ dx=\frac{x}{2}+\frac{1}{4}\cdot sin\ 2x+C$

147. $I_n=\int_0^{\frac{\pi}{2}} sin^n x\,dx=\int_0^{\frac{\pi}{2}} cos^n x\,dx$

$$I_n=\frac{n-1}{n}I_{n-2}$$

$$=\begin{cases}\frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{4}{5}\cdot\frac{2}{3}\ (n\text{为大于1的正奇数}),\ I_1=1\\ \frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{3}{4}\cdot\frac{1}{2}\cdot\frac{\pi}{2}\ (n\text{为正偶数}),\ I_0=\frac{\pi}{2}\end{cases}$$

证明①：$I_n=\int_0^{\frac{\pi}{2}} sin^n x\,dx=-\frac{1}{n}\cdot sin^{n-1}x\cdot cos\,x\Big|_0^{\frac{\pi}{2}}+\frac{n-1}{n}\int_0^{\frac{\pi}{2}} sin^{n-2}x\,dx$

$$=-\frac{1}{n}(sin^{n-1}\frac{\pi}{2}\cdot cos\frac{\pi}{2}-sin^{n-1}0\cdot cos0)+\frac{n-1}{n}\int_0^{\frac{\pi}{2}} sin^{n-2}x\,dx$$

$$=\frac{n-1}{n}\int_0^{\frac{\pi}{2}} sin^{n-2}x\,dx=\frac{n-1}{n}I_{n-2}$$

当n为正奇数时

$$I_n=\frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{4}{5}\cdot\frac{2}{3}\cdot\int_0^{\frac{\pi}{2}} sinx\,dx$$

$$=\frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{4}{5}\cdot\frac{2}{3}\cdot(-cos\,x)\Big|_0^{\frac{\pi}{2}}$$

$$=\frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{4}{5}\cdot\frac{2}{3}\cdot 1$$

特别的，当$n=1$时，$I_n=\int_0^{\frac{\pi}{2}} sinx\,dx=(-cos\,x)\Big|_0^{\frac{\pi}{2}}=1$

当n为正偶数时

$$I_n=\frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{3}{4}\cdot\frac{1}{2}\cdot\int_0^{\frac{\pi}{2}} sin^0 x\,dx$$

$$=\frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{3}{4}\cdot\frac{1}{2}\cdot(x)\Big|_0^{\frac{\pi}{2}}$$

$$=\frac{n-1}{n}\cdot\frac{n-3}{n-2}\cdots\cdots\frac{3}{4}\cdot\frac{1}{2}\cdot\frac{\pi}{2}$$

特别的，当$n=0$时，$I_n=\int_0^{\frac{\pi}{2}} sin^0 x\,dx=(x)\Big|_0^{\frac{\pi}{2}}=\frac{\pi}{2}$

证明②：$I_n=\int_0^{\frac{\pi}{2}} cos^n x\,dx\cdots\cdots$亦同理可证

附录：常数和基本初等函数导数公式

1. $(C)' = 0$ (C为常数)

2. $(x^{\mu})' = \mu \cdot x^{\mu-1}$ $(x \neq 0)$

3. $(\sin x)' = \cos x$

4. $(\cos x)' = -\sin x$

5. $(\tan x)' = \sec^2 x$

6. $(\cot x)' = -\csc^2 x$

7. $(\sec x)' = \sec x \cdot \tan x$

8. $(\csc x)' = -\csc x \cdot \cot x$

9. $(a^x)' = a^x \cdot \ln a$ (a为常数)

10. $(e^x)' = e^x$

11. $(\log_a x)' = \dfrac{1}{x \cdot \ln a}$ $(a > 0)$

12. $(\ln x)' = \dfrac{1}{x}$

13. $(\arcsin x)' = \dfrac{1}{\sqrt{1-x^2}}$

14. $(\arccos x)' = \dfrac{1}{-\sqrt{1-x^2}}$

15. $(\arctan x)' = \dfrac{1}{1+x^2}$

16. $(\text{arccot}\, x)' = -\dfrac{1}{1+x^2}$

说 明

1. 感谢本团队诸成员的高数老师的谆谆教导，感谢本团队诸成员间的合作,感谢所有支持本讲义编辑的支持者

2. 本讲义为方便各位学友阅读，排版采用每一单面都是一个或几个完整证明过程的原则

3. 由于本讲义编辑的比较匆忙，难免有些推导和输入错误，还望广大学友给予批评和指正。反馈邮箱 2633968548@qq.com

4. 各位有意愿下载的学友可以到百度文库和豆丁网上下载，也可加入 QQ 群 290986718 到群分享下载

2013 年 5 月

献给

我们的

大一